GROUNDWATER STUDY GUIDE

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PUB IE-004(90) Rev

Introduction

To educators

Cool, clear water is a precious and vulnerable resource. In Wisconsin, more than 70% of us depend on groundwater for drinking. Agriculture—and thus our food supply—depends on it. Industry depends on it. Yet, until recently, most people rarely thought about this buried treasure. Today we're becoming more aware of groundwater, mainly because of increasing reports of contamination.

This study guide is designed to help you and your students begin thinking about groundwater — where it comes from, why it's important, and how it can be conserved and protected. The guide includes a brief overview of groundwater, a glossary, suggested activities, and a list of related Department of Public Instruction objectives for science, health and social studies. Also included is a list of resource publications, audio-visual materials and organizations. The guide is designed to stand alone, yet complements the *Wisconsin Natural Resources* Magazine supplement "Groundwater: Protecting Wisconsin's Buried Treasure" (see Resources).

Talk with your students before beginning your lessons to learn what they already know and think about groundwater. *What is groundwater? Where does it come from? Why is it important? How can it become contaminated? How can we protect it?* By learning your students' thoughts and opinions about groundwater, you can help them connect new concepts with what they already know. We encourage you to adapt the activities to meet your students' needs. You are welcome to reproduce any part of this guide for distribution to students and other educators.

The groundwater activities are written for 6th to 9th grade Earth Science classes. Many are suitable for older or younger students and most are applicable to other subjects. Selected Wisconsin DPI objectives for science, health, and social studies are listed in the Appendix. You will find a list of relevant objectives for these subjects at the beginning of each activity: Two letters represent the subject (SC = science, EH = environmental health, SS = social studies). A single letter followed by a number corresponds to the outline in the Appendix (e.g. SC:A1 = science, objective A, subobjective 1).

Wisconsin's Buried Treasure

Picture all the water in lakes and streams in the United States. Now, try to imagine 20 times that much water hidden underground, filling cracks and pores in the earth. That's 30-60 quadrillion gallons of water within 1/2 mile of the earth's surface! However, this vast supply of groundwater isn't evenly distributed. Some areas have ample supplies of usable groundwater, other areas have little.

Wisconsin is water-rich. In fact, our state's name comes from the Chippewa word "Wees-kan-san" which means "gathering of waters." You're probably aware of the large amounts of water in our lakes and rivers, but did you know that two quadrillion gallons of water—enough to cover the entire state to a depth of 30 feet—lie hidden underground?

What is Groundwater?

Groundwater originates as rain or snow. As precipitation falls on the earth's surface, some evaporates, some runs off over land into lakes and streams and some soaks into the ground. A portion of water that enters the soil is taken up and used by plants. (A large, leafy tree can take up a ton of water in a day!) The rest percolates deeper into the earth.

Not all water found in the ground is groundwater. "Groundwater" refers specifically to water that is held in the saturated zone below the water table. Rock and soil material stores water in spaces, much like a sponge. Imagine two sponges, stacked one on top of the other. The bottom sponge has been soaked in water. It represents the "saturated zone"—all of its pore spaces are filled with water. The top sponge has been wetted, but the water has been squeezed out. This sponge represents the "unsaturated zone"—some of the spaces are filled with water, some are filled with air. The boundary between the two zones represents the "water table." The water in the saturated sponge represents groundwater.

Where is it Found?

Contrary to popular myths, groundwater doesn't flow in mysterious underground rivers nor is it stored in underground lakes. Most groundwater is found in aquifers—underground layers of porous rock and soil that are saturated with water (like a sponge). Four major aquifers underlie most of our state, but the amount and quality of water they contain is variable.

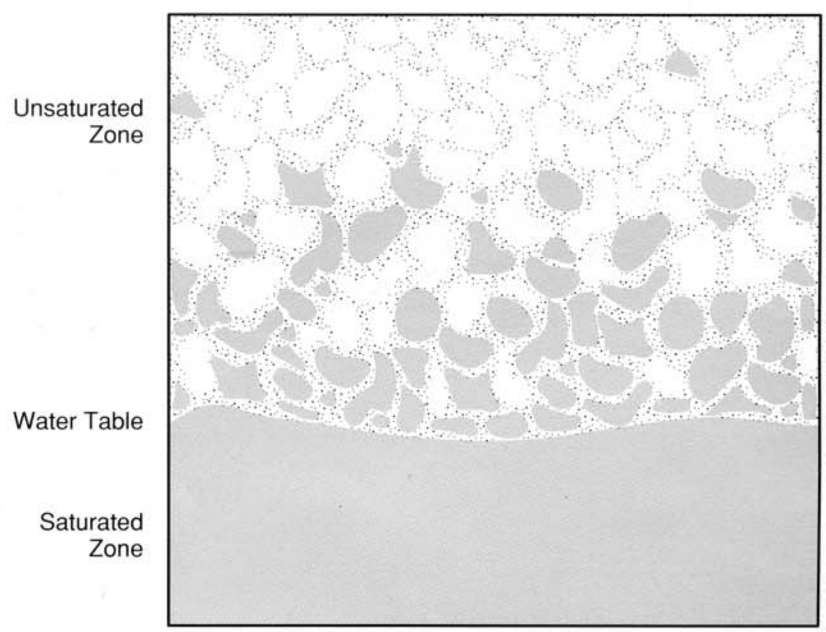
The composition of soil—clay, loam, silt, sand or rock—generally determines the amount of groundwater and the depth at which it is found in a given area. Coarse materials such as sand and gravel, which have large spaces between grains, allow for excellent storage and movement of water. On the other hand, fine-grained materials such as clay or shale restrict water movement.

Like surface water, groundwater flows from higher to lower elevations, moving through connected spaces in soil material. But, unlike water in rivers and streams, groundwater moves slowly—from a few inches to a few feet per day. Variation in rainfall and pumping from wells can affect the rate and direction of groundwater flow.

Why is it Important?

Water has helped shape Wisconsin's geography, history and industry. More than 70% of Wisconsin's homes use groundwater. An average family of four uses 255 gallons of water/day. Household use accounts for 20% of the water withdrawn from the ground in Wisconsin. Cheese, beer, papermaking and other industries also require a lot of water; Wisconsin's industries withdraw 40% of the groundwater used in the state. Commercial businesses use 7%. Thirteen percent of the water withdrawn from the ground is used for irrigation and livestock production. All together, we use almost 1/2 billion gallons of groundwater in Wisconsin each year.(see *Groundwater Supplement*, pg. 3)

Groundwater provides the base-flow for most streams and rivers and is the primary source of water for most lakes and wetlands. So it's also important to wildlife and to recreation such as fishing, boating and swimming. (See *Groundwater Supplement*, pg. 5)



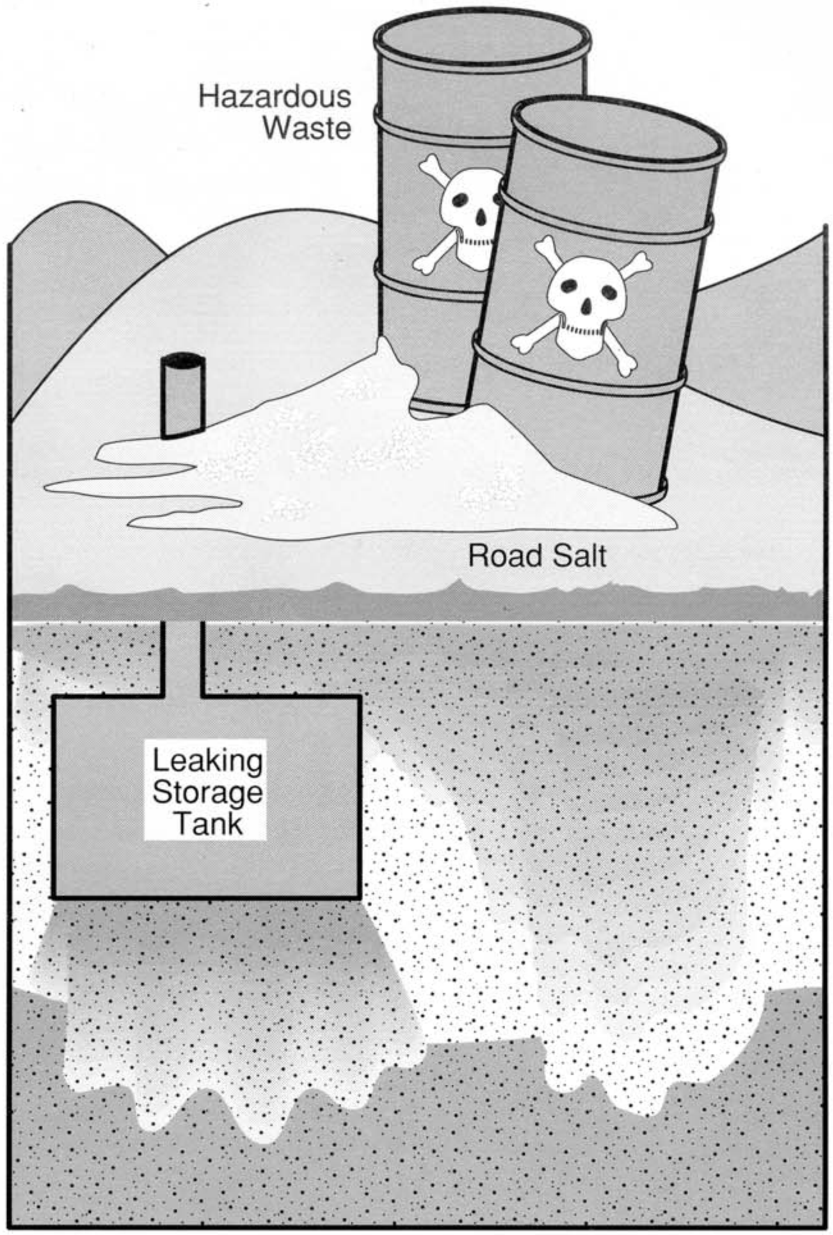
How Does Groundwater Become Contaminated?

Groundwater is never a pure combination of hydrogen and oxygen atoms (H_20). As water soaks into the ground, it dissolves minerals and gases from the rock material it encounters. "Natural" groundwater contains many dissolved minerals and gases that may give it a particular taste, odor or color. Typical concentrations of most naturally-occuring contaminants pose no health risk.

Percolating groundwater can also carry human-made pollutants. Contamination can be serious if groundwater contains substances (natural or human-made) that pose a health threat—bacteria, viruses, nitrate, metals such as mercury or lead, pesticides and other synthetic organic compounds. Carelessness and lack of understanding can lead to groundwater contamination from a variety of sources including:

- leaking underground petroleum pipes and tanks
- use and storage of road salt
- improper use, disposal and storage of hazardous materials
- improper disposal of solid waste
- practices such as over-application of fertilizers and pesticides
- improper management of animal wastes

Since groundwater flow is generally slow, pollution may take decades to show up in a well, lake or stream. Removal of contaminants is expensive and difficult (if not impossible), so **prevention** of contamination is the key to maintaining groundwater quality.



How Can You Help?

There are many things you can do to help protect Wisconsin's buried treasure:

- Become more aware of groundwater use in your area and how everyday actions can affect groundwater.
- Conserve water in your home. Don't allow the water to run while you wash the car, do dishes or brush your teeth. Take shorter showers (each minute of a shower uses 10 gallons of water), water lawns and gardens before 10 am or after 6 pm to reduce evaporation loss.
- Become involved in community waste disposal problem solving.
- Recycle aluminum, tin, paper, newsprint and plastic containers.
- Make sure your well is properly located, constructed and maintained. Test your well annually for bacteria and nitrate levels.
- Make sure your septic system is properly located, constructed and maintained.
- Become aware of alternatives to using hazardous household chemicals.
- Follow recommended procedures for using, storing and disposing of household chemicals.
- If you use pesticides and fertilizers, apply them in recommended amounts.
- Report illegal or abandoned waste sites.
- Report incidents of improper waste disposal or chemical spills.
- Attend public meetings and correspond with government officials on groundwater management issues.

We should all treat water as if our lives depend on it—they do!

Note: Words that appear in italic are defined in the glossary.

Buried Treasure

- Wisconsin's groundwater would cover the state's 36 million acres 30 feet deep
- more than 70% of us drink groundwater
- There are more than 700,000 private or municipal wells inWisconsin
- Wisconsin industries use 614 million gallons of water/day
- Livestock farms use 89 million gallons of water/day
- Irrigation equipment extracts 84 million gallons of groundwater/day
- Groundwater provides the base flow of most streams and rivers
- Groundwater is the source of water for most lakes and wetlands

Glossary

Aquifer: A rock or soil layer capable of storing, transmitting and yielding water to wells.

Artesian: A condition referring to groundwater that is under enough pressure to rise above the aquifer containing it. Sometimes artesian wells will flow at the surface.

Coliform bacteria: A group of bacteria found in animal feces or sewage whose presence in well water may indicate contamination carried by surface water to groundwater. Water containing high levels of coliform bacteria should not be consumed.

Dolomite: Calcium magnesium carbonate, a common rock-forming mineral. Many rocks in Wisconsin generally referred to as limestone are actually dolomite.

Dump: An open, unsanitary disposal site used before the existence of licensed, controlled sanitary landfills. Opening a dump is now illegal in Wisconsin.

Evaporation: The process by which water is changed from a liquid or solid into a vapor.

Groundwater: Water beneath the surface of the ground in a saturated zone.

Hazardous waste: Waste that causes special problems for living organisms or the environment because it is poisonous, explosive, dissolves flesh or metal, ignites easily (with or without a flame) or carries disease.

High capacity well: A well that withdraws more than 100,000 gallons of water per day.

Hydrologic or water cycle: The complete cycle of phases through which water passes from the atmosphere to the earth and back to the atmosphere.

Impermeable: Having a texture that does not permit water to move through quickly.

Infiltration: The movement of water into and through soil.

Leachate: A liquid formed by water percolating through soluble waste material. Leachate from a landfill has a high content of organic substances and dissolved minerals.

Limestone: A sedimentary rock consisting chiefly of the mineral calcite (calcium carbonate).

Permeability: The capacity of soil or rock to transmit a fluid, usually water.

pH: From the phrase p(otential) of H(ydrogen), pH is a measure of acidity or alkalinity. As a solution becomes more acidic, its pH decreases; as it becomes less acidic its pH increases. A solution with a pH of 7 is considered neutral; a pH less than 7 is acidic and a pH greater than 7 is considered alkaline.

Sanitary landfill: A specially engineered site for disposing solid waste on land. Constructed in a way that reduces hazards to health and safety.

Solid waste: All solid and semi-solid wastes, including trash, garbage, yard wastes, ashes, industrial waste, swill, demolition and construction waste and household discards such as appliances, furniture and equipment.

Spring: A natural discharge of water at the ground's surface.

Static water level: The elevation above sea level of the surface of water in monitoring wells. Used to determine the direction of groundwater flow.

Transpiration: The release of water vapor and waste products through the pores (stomata) of plants.

Volatile Organic Chemicals (VOCs): a group of commonly used chemicals that evaporate, or "volatilize" when exposed to air.

Water table: The level below which the soil or rock is saturated with water. The upper surface of the saturated zone.

Well: A vertical excavation that taps an underground formation; in Wisconsin, usually to obtain a source of water, to monitor the quality of groundwater or to determine the elevation of the water table.

How many gallons of water does it take to produce:

- a steak? . . . 3,500
- 20 lb turkey? . . . 16,300
- an egg? . . . 120
- a ton of steel? . . . 60,000
- a car? . . . 30,000
- a gallon of gasoline . . . 70
- a ton of paper? . . . 32,000

The Water Cycle

'Round and 'Round it Goes!

Goals: To help students understand Earth's water cycle, the interrelatedness of water in all its forms, and how human activities can affect water as it passes through the cycle.

Subjects: Science

DPI Objectives: SC:B3-B5

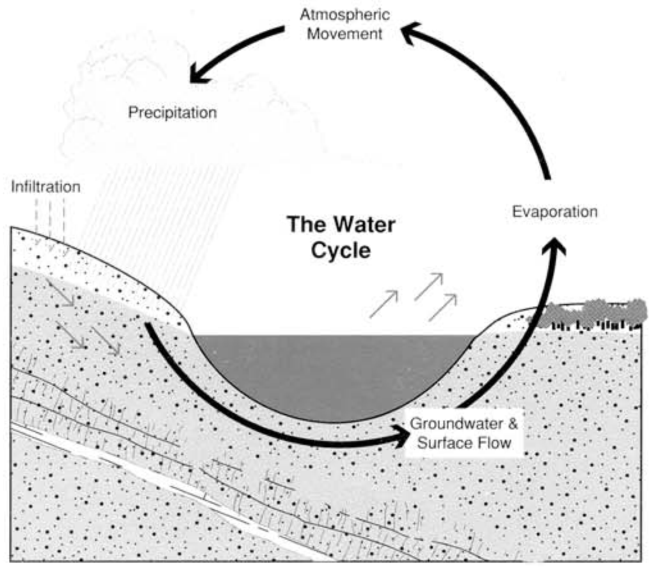
EH: A3, B4, C1

SS: B2

Grades: 6-9

Materials:

- Groundwater and Land Use in the Water Cycle poster
- 'Round and 'Round it Goes! activity sheet
- Dictionary



Background: Water is our most recycled resource. Consider, for example, that the water you bathed in this morning may have contained the same molecules of water that washed over a South Pacific coral reef a million years ago! The amount of water on Earth is basically constant, but the distribution of water changes over time and space due to a dynamic process called the *hydrologic or water cycle*. The water cycle is powered by solar energy and gravity.

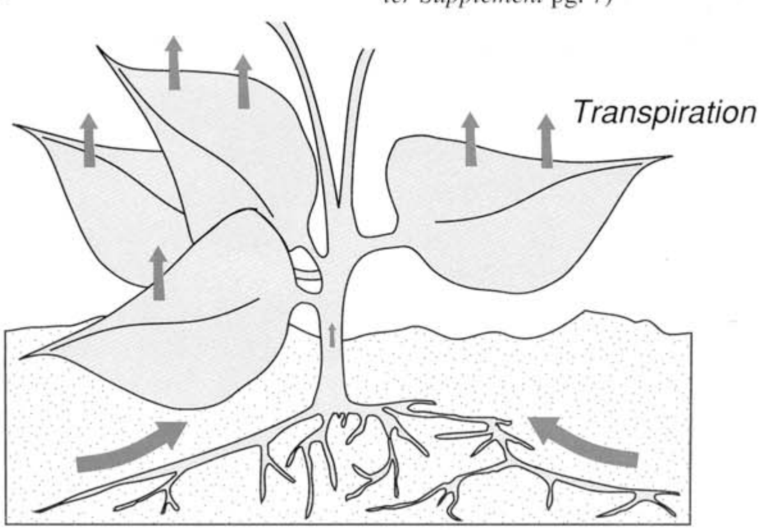
Warmth from the sun causes *evaporation* of water from lakes, streams and soils. Solar energy also drives a process called *transpiration*—the release and evaporation of water from tiny pores in the leaves of plants. Evaporated and transpired water vapor is stored in the atmosphere until it condenses and is pulled by gravity back to earth as rain, sleet, snow, hail, dew or frost.

Up to 80% of this precipitated water is returned directly to the atmosphere by evaporation. The rest may run off over land and into lakes and streams or may soak into the ground. Some of the water that soaks into the ground stays in the unsaturated zone. This zone is the rock or soil layer in which some of the spaces between particles are filled with air and some are filled with water. Some of the water in the unsaturated zone is taken up by plant roots and returned to the atmosphere by transpiration.

The rest of the water is pulled deeper into the ground by gravity, filling all the cracks and spaces in the underlying layers of soil, gravel and rock. Water in the saturated zone is called *groundwater*. The top of the saturated zone is the *water table*. Water continues to move underground from areas of high elevation toward lowland areas. This movement is generally slow, from a few feet per day to a few feet per year. Wherever the water table meets the land surface a spring may form or groundwater may seep into to a lake, stream, wetland or ocean. Once above ground, the water can evaporate and return to the atmosphere, and the water cycle begins again.

Human activities may affect the quality of water at any point in the cycle. Air pollution can change the chemical composition of rain and snow. Runoff from rainfall and snow melt can pick up soil, excess plant nutrients, pesticides, animal wastes, and municipal and industrial pollutants as it flows over land and into lakes and streams.

Contaminated runoff can also soak into the ground and pollute groundwater. Water percolating through soil and rock may pick up natural minerals or other contaminants. Knowledge of the water cycle can help us understand how water becomes polluted and how pollution can be prevented. (see *Groundwater Supplement* pg. 7)



Procedure:

1. Distribute copies of the poster. Discuss the background information.

2. Working in small groups, complete the activity sheet. Use the "Water Cycle" poster as a reference.

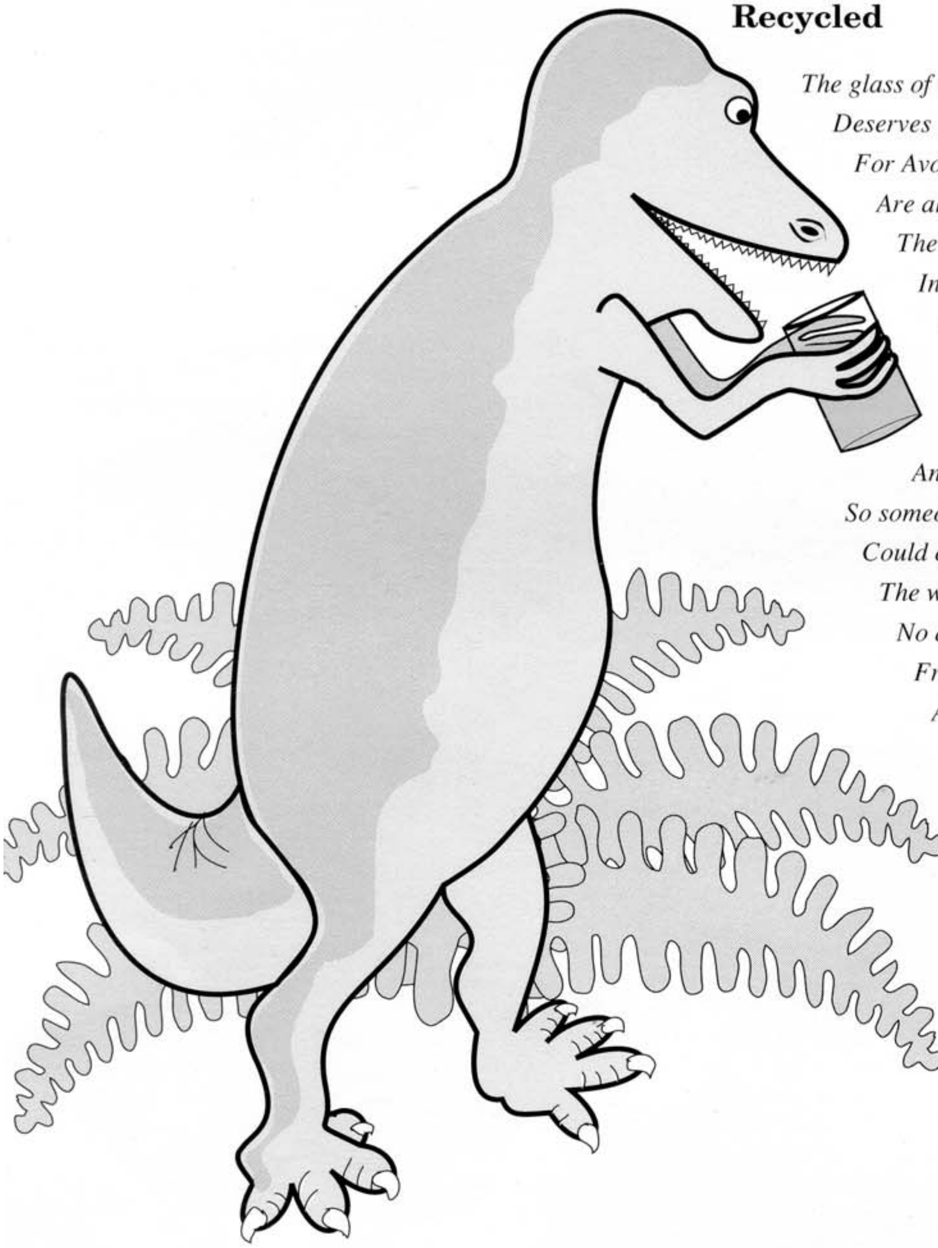
Going Beyond:

1. Research how long it might take a drop of water to pass through the entire water cycle.

2. Design and construct a graphic or mural of the water cycle for your community. Include the community's water system and local human impacts on the water cycle.

3. Create a mini-water cycle for your classroom. In an aquarium (terrarium) or wide-mouth glass jar, put a one inch layer of gravel for drainage. Next, add a layer of peat moss and then a layer of soil. Small houseplants such as violets and ferns can be planted in the terrarium. Water your terrarium lightly and cover it with a piece of glass, leaving approximately 1/2" uncovered for air movement. Keep the terrarium in your classroom and watch what happens over the next week. The plants will take moisture from the soil and release (transpire) it from their leaves. Water molecules will condense on the glass and "rain" back onto the soil.

Adapted from: ***Groundwater Study Guide.*** *1984. Wisconsin Department of Natural Resources, Bureau of Information and Education.*

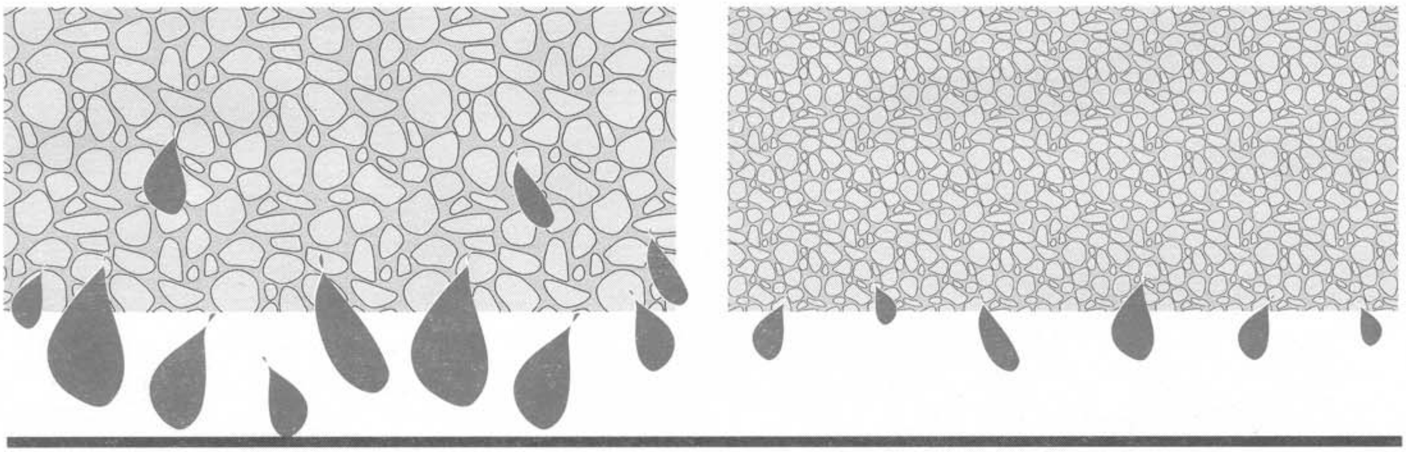


Recycled

The glass of water you're about to drink
Deserves a second thought, I think
For Avogadro, oceans and those you follow
Are all involved in every swallow.
The molecules of water in a single glass
In number, at least five times, outclass
The glasses of water in stream and sea,
Or wherever else that water can be.
The water in you is between and betwixt,
And having traversed is thoroughly mixed,
So someone quenching a future thirst
Could easily drink what you drank first!
The water you are about to taste
No doubt represents a bit of waste
From prehistoric beast and bird—
A notion you may find absurd.
The fountain spraying in the park
Could well spout bits of Joan of Arc,
or Adam, Eve, and all their kin;
You'd be surprised where your drink has been!
Just think! The water you cannot retain
Will some day hence return as rain,
Or be held as the purest dew.
Though long ago it passed through you!

Verne N. Rockcastle

How Groundwater Moves



Porosity and Permeability

Goals: To help students understand how characteristics of soil particles (e.g., size and shape) affect the porosity and permeability of soil and thus, groundwater storage and movement.

Subjects: Science, Math

DPI Objectives: SC: A1-A3

Grades: 6-9

Materials:

- ❖ Porosity and Permeability activity sheet
- ❖ gravel*
- ❖ sand*
- ❖ clay*
- ❖ potting soil*
- ❖ containers for used clay, soil, sand and gravel

For each group of 2-3 students:

- ❖ 4 test tubes
- ❖ test tube rack
- ❖ 100 ml glass beaker
- ❖ small funnel
- ❖ 100 ml graduated cylinder
- ❖ 4 sheets of round filter paper
- ❖ glass marking crayon

* These materials must be very dry. Spread soil materials on a cookie sheet and dry in oven at 250-275° F. Break up clay and potting soil after drying so that no clumps remain.

Background: Just how solid is "solid ground?" The material beneath our feet is rarely solid. Soil is made up of particles of rock and the spaces between these particles. The amount of space between soil particles is called porosity. You can estimate the porosity of a soil by measuring the amount of water it can hold.

Underground, water percolates down through soil and flows from higher elevations (such as a hill) to lower elevations. The ease with which water moves through a soil or rock type is called *permeability*. You can estimate the permeability of soil by timing how quickly water can flow through it.

Physical characteristics of soil particles, such as size and shape, influence the porosity and permeability of soils and rocks. Coarse materials, like gravel and sand, tend to be both porous (they have large pore spaces that can fill with water) and permeable (water passes easily between the large particles). Some fine materials, such as clay, may hold a lot of water yet transmit very little because water cannot move easily through the tiny pore spaces.

An *aquifer* is a rock or soil formation that can both store and transmit a significant amount of water. A well drilled in a sand aquifer is likely to yield a lot of water; a well drilled in clay will probably yield little.

Procedure:

A) Predicting porosity and permeability.

1. Examine the gravel, sand, soil and clay. Predict which materials can hold the most water and which ones water will flow through fastest. Record your predictions on the chalkboard. Then, in small groups, either investigate each material or assign groups to one soil material and compile class results on the chalkboard.

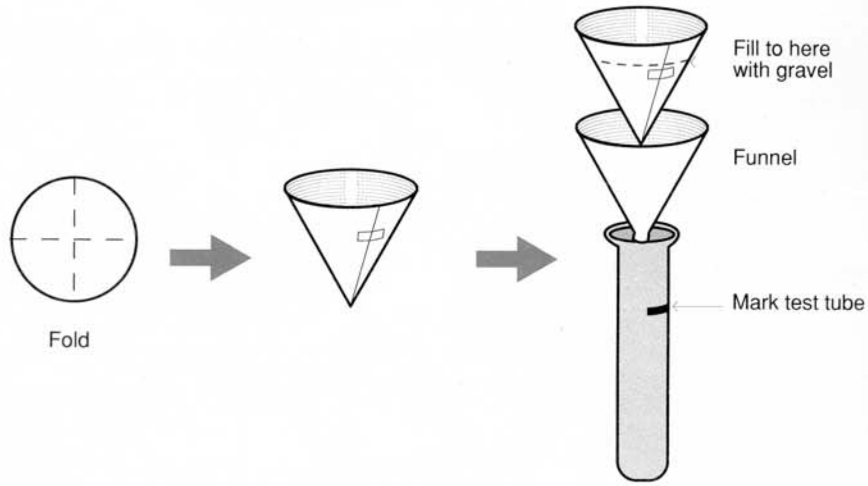
B) Measuring porosity.

1. With a marking crayon, place a line about 1/2 way up the side of a small beaker. Fill the beaker with water to the line. Pour this water into a 100 ml graduated cylinder. Record this volume on your data sheet under "total volume." Dry the beaker.

2. Fill the beaker with gravel to the line and fill the graduated cylinder to the 100 ml mark with water. Pour water from the graduated cylinder into the beaker until it reaches the line. Record the volume of water needed to saturate (fill the pores of) the gravel on your data sheet under "pore space." Divide this volume by the "total volume" and multiply by 100 to get percent pore space in your sample of gravel. Record this value under "porosity" (% pore space). Repeat the investigation with samples of sand, soil and clay. (Note: For potting soil and clay, make sure that the water has time to soak in completely.) Record your results.

C) Measuring permeability.

With a marking crayon, place a line about 1/2 way up a test tube. Put the test tube in the rack and put the stem of a small funnel inside the test tube. Fold a circular filter paper into quarters, open it into a cone, and insert it into the funnel. Fill the cone with gravel to about 1/2" from the top. Pour water from a beaker into the filter. Using a clock, a watch or by counting, time how long it takes to fill the test tube to the line. Record the results on your data sheet under "permeability." Return the sample of gravel to the used gravel container and discard the filter paper. Repeat the experiment with sand, soil and clay.



Make bar graphs of your results and complete questions on the "Porosity and Permeability" activity sheet. Discuss your results and answers:

- Did your results match your predictions?
- Which material is the most permeable? Why?
- Which is the least permeable? Why?
- Which soil is the most porous? Why?
- Which is the least porous? Why?
- If you drilled a well in these materials, which one do you think would yield the most water?

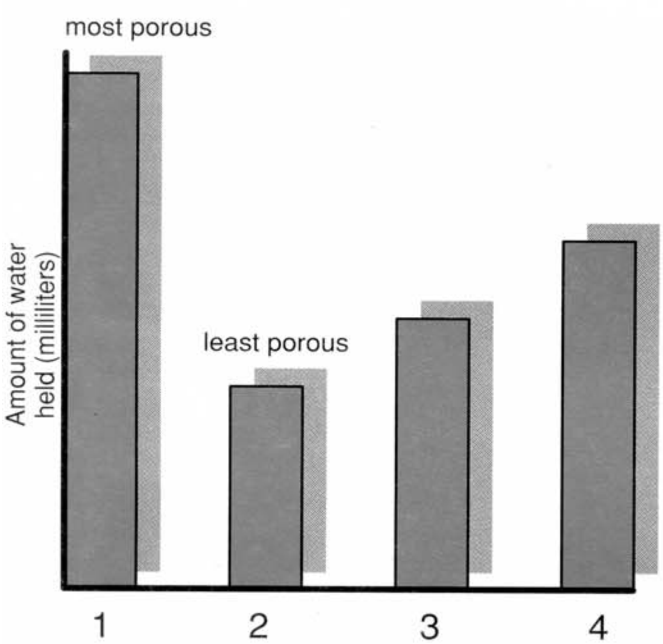
Going Beyond:

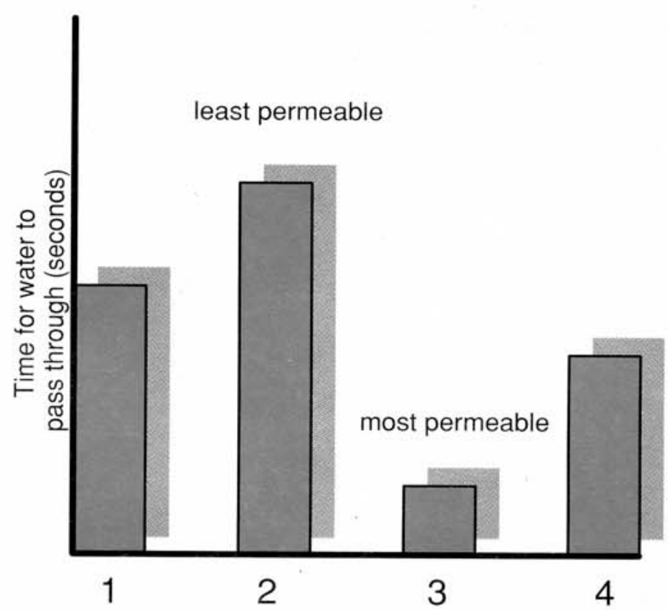
1. Invite a certified soil tester or county on-site waste disposal (septic system) specialist to discuss how porosity and permeability of soil and rock are measured in the laboratory and in the field.

2. Compare the porosity of a variety of rocks. Record the weights of small pieces of limestone, sandstone, shale, granite, obsidian, lava, etc. Soak the rocks in water for several days. Remove them from the water and pat them dry. Weigh the rock pieces again and record your results. Compare the mass of each rock before and after soaking. Discuss your results in terms of the rock's ability to hold water. Note: water may move through cracks in rock as well as through the pore spaces. The amount of cracking in a rock determines its "secondary porosity."

3. Investigate the effect of organic material on a soil's permeability and its ability to filter contaminants. Prepare four "contaminated" water samples containing 1) vegetable oil, 2) vinegar, 3) detergent and 4) green food coloring. Pour small amounts of each sample through 1) sand, 2) sand + potting soil, 3) clay, 4) clay + potting soil. Compare filtering times of the different soils. Compare appearance of contaminant samples before and after filtering (use pH paper for vinegar). Filter plain tap water as a control.

Adapted from: ***Groundwater: A Vital Resource****. Cedar Creek Learning Center and the Tennessee Valley Authority.*





Well, Well, Well...

Goals: To help students understand how water moves underground, how a well works to recover groundwater, and how withdrawal of groundwater can affect the water table.

Subjects: Science, Home Economics, Environmental Science

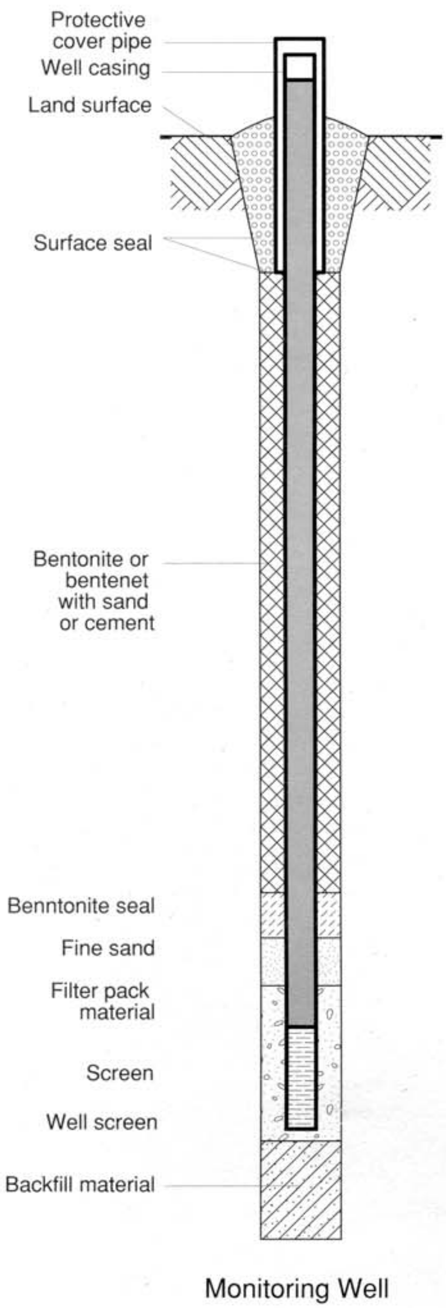
DPI Objectives: SC: A1, A2, B3, B5

EH: C1, C4

Grades: 6-9

Materials:

- Well, Well, Well... activity sheet



Monitoring Well

- one 10 gallon aquarium (may be adapted for 5 gallon aquarium)
- one 5 gallon bucket filled with coarse, clean sand
- one quart of aquarium gravel
- one piece 1" wide diameter plastic tubing
- three pieces 1/3" outside diameter glass tubing:

  one piece, 20" long

  two pieces, 4" long
- two pieces 1/3" outside diameter rubber tubing:

  one piece 3' long

  one piece 2' long
- two glass rods 12" long (or similar diameter wooden dowels)
- two #7 rubber stoppers:

  one 1-holed

  one 2-holed
- one 500 milliliter Erlenmeyer glass flask
- one hand pump/siphon*
- small nail
- watering can or spray bottle
- 3" X 3" piece of cheesecloth
- small rubber band
- aquarium glue
- green food coloring
- 5 gallons of water

* available at sporting goods stores, pet shops and hardware stores

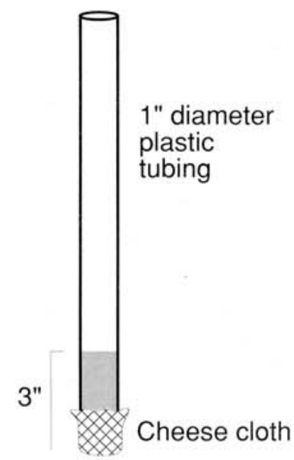
Background: *Wells* are constructed to bring groundwater to the land surface so we can use it (or monitor its quality). Holes are drilled and pipes put in the ground to a depth below the water table. Pumps are connected to the well pipe so that water in and around the well is drawn up the pipe and into a house or wherever the water is used.

Following are instructions for constructing a well model. You can use the model to demonstrate how surface water soaks into the ground to become groundwater and how a pump recovers water. By adding food coloring to represent a contaminant, you can also use the model to demonstrate how groundwater can become polluted.

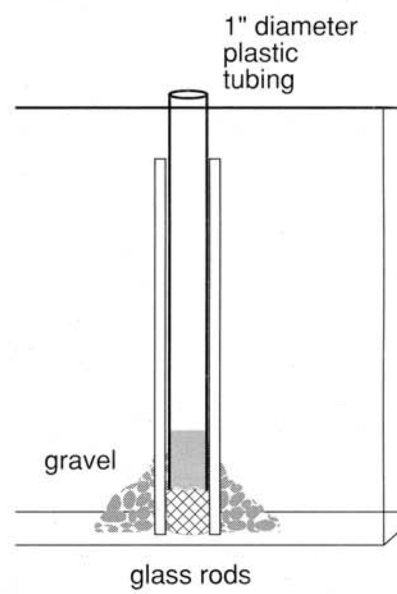
Procedure:

A) Preparation.

1. Using a small nail, make approximately 30 1/16" diameter holes beginning at one end of the 1" diameter plastic tubing and extending three inches from that end. Cover the bottom of the tube with cheesecloth and secure with a small rubber band. This will prevent sand from entering the bottom of the tube later.

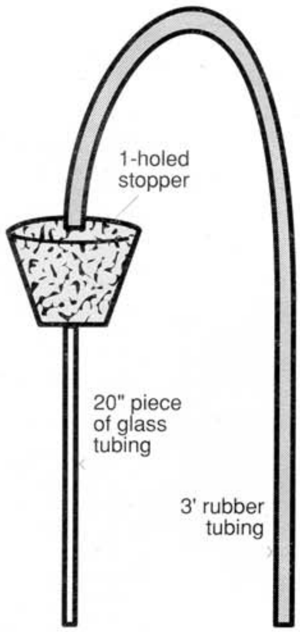


2. Using aquarium glue, attach the two glass rods (or dowels) and the 1" diameter plastic tube to the long side of the aquarium perpendicular to the bottom. Allow glue to dry.



3. Place gravel so that all holes at the bottom of the 1" diameter plastic tubing are covered. The gravel will help keep sand from entering the well during pumping.

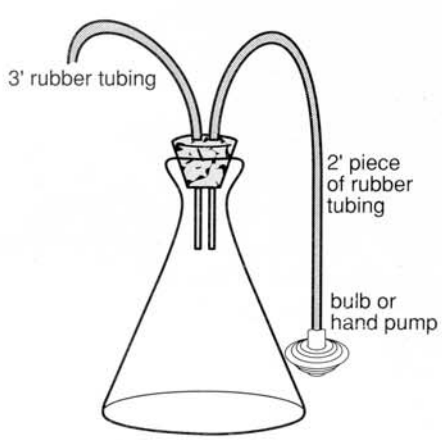
4. Insert the 20" piece of glass tubing into the one-holed stopper so that the tube extends one to two inches above the top of the stopper.



5. Attach one end of the 3' rubber tubing to glass tube extending out of the stopper.

6. Insert this assembly into the 1" plastic tube in aquarium.

7. Insert two 4" pieces of glass tubing into holes of 2-holed stopper so that 1" of tubing extends above the stopper. Attach the loose end of 3' rubber tubing to one of the glass tubes extending from 2-holed stopper.



8. Attach one end of 2' piece of rubber tubing to the other glass tube extending from the stopper.

9. Insert stopper into the flask.

10. Attach the hand pump/siphon to the other end of the 2' tubing. Check that all connections are airtight.

11. The model works best when the flask is positioned lower than the aquarium to create a continuous siphon thus eliminating the need to continuously pump.

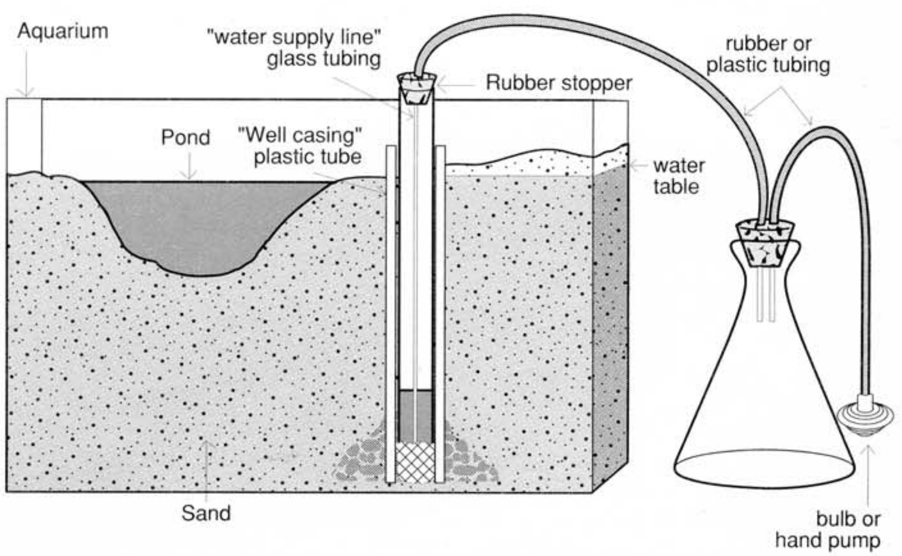
12. Fill the aquarium 1/2 to 3/4 full with sand. Create a depression in sand opposite to the well. This simulates a pond or lake.

13. Add water to the aquarium so that it's about 1/2 full. The completed model should look like the illustration below.

B) Demonstration.

1. Discuss the model. Identify the groundwater and the water table. Begin to slowly pump water from the well. Note the level of the water table and pond surface. As the surface level of the pond is lowered, a rain storm may be simulated by pouring water from a watering can over the land and water.

2. Experiment with more rainfall ("recharge") than pumping to simulate a wet year, and with more pumping ("withdrawal") than rainfall to simulate a drought. Groundwater "overdraft" occurs when the rate of withdrawal of water is greater than recharge, resulting in a lowering of the water table. Observe the runoff and infiltration. When you are finished with the experiments, continue pumping until the flask is full.



3. Empty the flask and "pollute" the pond with green food coloring. Continue the demonstration with polluted water (food coloring represents a water soluble pollutant). Point out that, unlike food coloring, many contaminants don't change the color, odor or taste of water. These contaminants are difficult to detect. Many other pollutants may be filtered out by soil or broken down by chemical or physical processes before they reach groundwater. Notice also that the dyes in the food coloring move at different rates through the soil.

Note: If using model for consecutive classes, leave time to flush dye pollutant from model (by adding water and pumping) or work dye contaminant into next demonstration, e.g. have students determine the source of contamination, find how much water/how much pumping is required to remove contaminant, etc.

C) Discussion.

1. Complete the activity sheet. Discuss your answers.

More ways to use your groundwater model

1. **Fertilizer/Pesticide Model:** Build the groundwater model as directed. Sprinkle powdered grape drink mix on the surface to represent fertilizer or pesticide put on a field. Sprinkle water over the surface to simulate rain. Observe and discuss.

2. **Landfill/Abandoned Waste Site Model:** Roll a paper towel into a ball and saturate it with food coloring. Bury it just beneath the surface to represent an improperly designed or abandoned waste disposal site. Pour water on the surface. Observe and discuss.

3. **Leaking Underground Storage Tank Model:** Fill a film canister with colored water and puncture it in several places with a pin. Bury it just beneath the surface (not along the side of the box). Pour water on the surface. Observe and discuss.

4. **Abandoned Well Model:** Puncture a drinking straw in several places with a pin and plug the bottom with clay. Bury the straw, plugged end down, in the sand to represent an abandoned well. Pour colored water into the abandoned well. Pump from the working well. Observe and discuss.

5. **Leaky Lagoon Model:** Cut the bottom off a small paper cup and puncture the bottom in several places with a pin. Partially bury the cup bottom in the sand to simulate a settling lagoon. Fill the lagoon with colored water. Pump from your well. Observe and discuss.

From: ***Groundwater Resources and Educational Activities for Teaching.*** *1989. Iowa Department of Natural Resources.*

Going Beyond:

1. Contact a licensed well driller (a list is available from your local DNR office). Arrange a field trip to a drilling site. Ask driller to show and discuss the drilling record. Using a flashlight, look down the new well (attach flashlight to a string to make sure it isn't lost down the well).

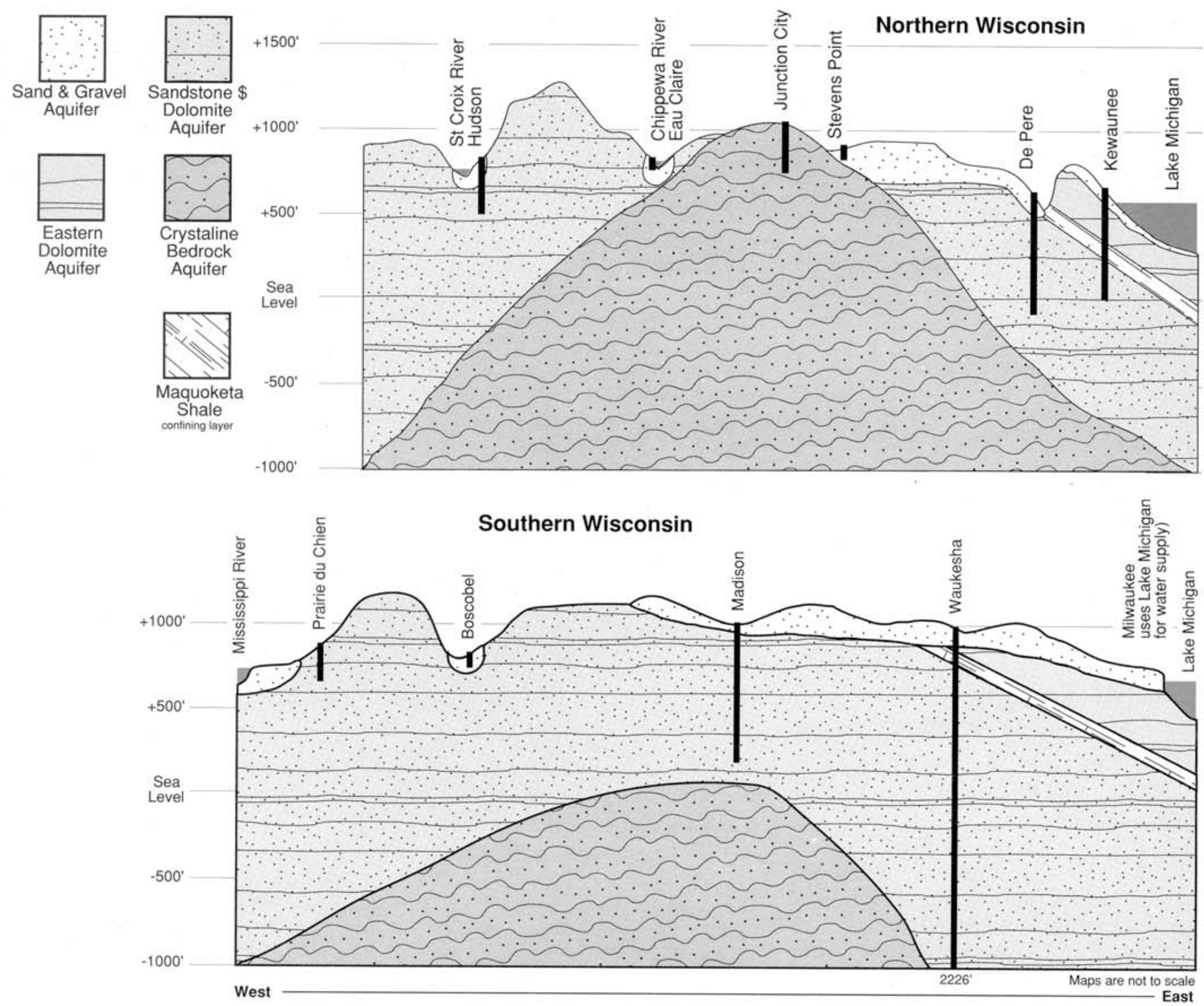
Attach a cork to a fishing line and lower down well to measure depth of the water table. When the cork floats, mark the spot on the fishing line that is even with the top of the well casing. Pull the line up and measure the length of line from the mark to the cork and subtract the distance that the casing extends above the ground. The resulting distance is the depth of the water table from the ground surface. Compare your measurement to the well driller's measurement.

Repeat your field trip when the well, pump and piping are complete and ask driller to explain how well and pressure tank work to bring water to the surface. Ask well driller to explain a "pitless adapter." Inspect the adapter with a flashlight. Collect a water sample for bacterial and nitrate analysis.

Adapted from: ***Groundwater Study Guide***. *1984. Wisconsin Department of Natural Resources, Bureau of Information and Education.*

A 2-dimensional Plexiglass Groundwater Flow Demonstration Model is available from the Central Wisconsin Groundwater Center. See Resources.

Wisconsin's Major Aquifers



Goals: To help students become familiar with Wisconsin's four major aquifers.

Subjects: Science, Environmental Science

DPI Objectives: SC: A2, A3, B3

Grades: 6-9

Materials:

- Wisconsin's Major Aquifers—overhead*
- Wisconsin's Aquifers—activity sheet*
- Wisconsin's Major Aquifers—teachers key
- colored pencils

* Two cross-sections of the state are provided. You may choose a northern or southern cross-section for this activity.

Background: An *aquifer* is an underground formation that can store and transmit water. Most of Wisconsin is underlain by thick, permeable deposits. These layers of rock and soil make up our state's four major aquifers: 1) the sand and gravel aquifer, 2) the eastern dolomite aquifer, 3) the sandstone and dolomite aquifer and 4) the crystalline bedrock aquifer. A few areas in northern Wisconsin are made up of clay soils overlying granite or other non-porous materials. Since these materials can't store or transmit much water, substantial well water supplies aren't available there. (see G*roundwater Supplement* pp. 10-11.)

1) The sand and gravel aquifer covers most of Wisconsin, except for the unglaciated areas in the southwestern part of the state. This aquifer layer was deposited by glacial ice and river floodplains between 10,000 and 1 million years ago. Many of the irrigated farmlands in southern and northwestern Wisconsin tap this aquifer. Because the top of the sand and gravel aquifer is also the land surface, the groundwater it contains may easily become contaminated.

2) The eastern dolomite aquifer lies beneath the sand and gravel aquifer in eastern Wisconsin, and extends from Door County to the Wisconsin-Illinois border. It is made up of the Niagara dolomite formation underlain by the Maquoketa shale formation. These layers were

deposited about 400 million years ago. *Dolomite* is like limestone and contains groundwater in interconnected cracks. The yield of water from wells in this aquifer is variable and depends on the number of fractures through which a well passes. Where this fractured formation is close to the land surface, groundwater may easily be contaminated.

The Maquoketa shale layer doesn't transmit water readily. This formation isn't important as an aquifer but as a confining layer or barrier between the eastern dolomite aquifer and the sandstone and dolomite aquifer.

3) The sandstone and dolomite aquifer is made up of layers of sandstone and dolomite bedrock. Water is found in fractures in these layers. In the sandstone layer, water also occurs in pore spaces between the loosely cemented sand grains. This aquifer covers the entire state, except for the north central region. Materials in the sandstone and dolomite aquifer were deposited between 425 and 600 million years ago. This is the principal bedrock aquifer for southern and western portions of the state. Most cities and industries in eastern Wisconsin also tap this deep aquifer.

4) The crystalline bedrock aquifer is made up of a variety of rock types formed between 600 and 4,000 million years ago. This granite-like rock formation underlies the entire state. In the north central region this aquifer lies directly beneath the sand and gravel aquifer. Water is stored in cracks that may be many feet apart. To draw water from this aquifer a well must pass through some of these cracks. Good quality water can be obtained from shallow wells in this formation, but wells that penetrate deep into the aquifer have been found to yield salty water because the water becomes concentrated with salts and minerals as it passes through many rock layers.

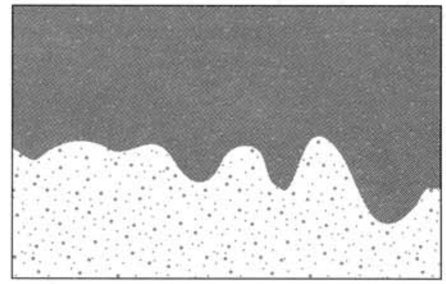
Procedure:

1. Discuss the background information.
2. Complete the activity sheet for either the northern or southern cross-section.
3. Discuss your answers, using "Wisconsin's Major Aquifers" overhead.

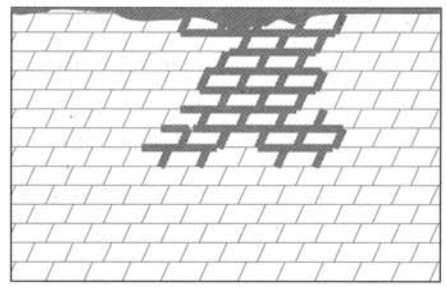
Going Beyond:

1. Visit your local water department and obtain a record of the aquifer layers under your community. Investigate what aquifer your town well taps, its depth, and how much water is pumped per minute, per day and per year. Investigate the water quality and treatment methods used.
2. Construct a geological model of your area using topographic, geologic, and groundwater susceptibility maps. Maps are available from the Wisconsin Geologic and Natural History Survey (see Resources). Using modeling clay, markers, and labels, show local soil and rock types, topography, depth to bedrock, depth to groundwater, and groundwater susceptibility. (This activity could be used as an art class project.)

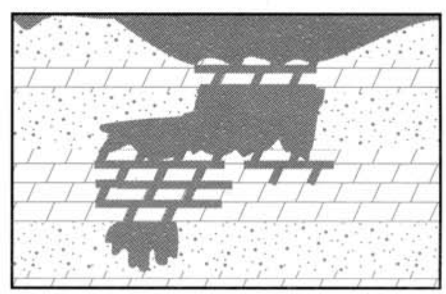
Adapted from: ***Groundwater Resources and Educational Activities for Teaching****. 1989. Iowa Department of Natural Resources.*



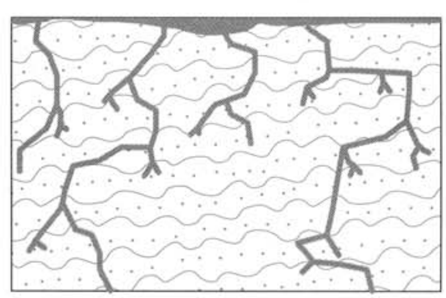
Sand & gravel aquifer



Dolomite



Sandstone & dolomite



Crystalline bedrock

A Plume of Contamination

Goals: To have students understand how contaminants can enter and move with groundwater and what is meant by "plume of contamination." To help students realize why it is often difficult to determine the source of groundwater contamination.

Subjects: Science, Health, Home Economics, Environmental Science

DPI Objectives: SC: A1-A3, B3

EH: B4, C4

Grades: 6-9

Materials:

- A Plume of Contamination activity sheet
- clear plastic shoe boxes* or large plastic deli boxes—one for demonstration and one for each group of 3-4 students
- sand
- powdered grape drink mix (do not add water)
- powdered lemonade mix (do not add water)
- for each group of 3-4 students:
  - watering cans or spray bottles
  - plastic straw, cut in half
  - pH paper
  - tape
- plastic shoe box lids or pencil erasers for props

* available at discount stores

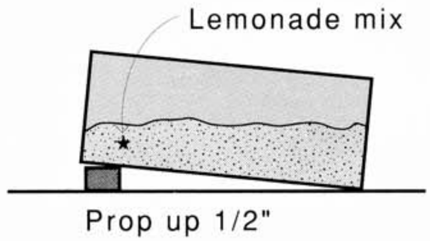
Background: Contaminants on the surface of the ground can move slowly through soils and reach groundwater. Contaminants spread outward from the point of origin, forming a plume which "points" to the source of contamination. A small amount of some contaminants can ruin a large quantity of groundwater.

Some chemical contaminants are easily detected by changes in color, odor, or taste of groundwater. However, most contaminants are "invisible" and require chemical testing for detection. Testing of many wells in an area may be required to determine the source of contamination.

Procedure:

A) Preparation.

1. Before class, fill one clear plastic shoe box for each group of 3-4 students with 1 inch of sand. Wet the sand with water and smooth off the surface. Station boxes around classroom.



2. Prop up one end of each box about 1/2 inch.

3. Make a small depression in the sand and add 1/2 teaspoon of dry lemonade mix at the elevated end. Cover the lemonade with sand. Vary the location of the lemonade contaminant in each box and keep a record of the contaminant location. After the demonstration, students will use pH paper to find the source of contamination.

B) Demonstration.

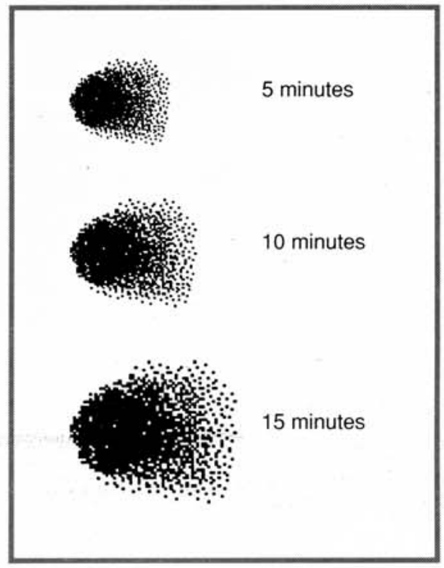
1. Prepare a plastic box as above, but don't add lemonade.

2. Make a small depression on the elevated side of the box. Place about 1/4 teaspoon of powdered grape drink mix in the depression. This represents a chemical contaminant.

3. "Rain" water on the contaminant, using the spray bottle or watering can. The "rain" should be light so the food coloring is diluted and seeps into the sand rather than running off the surface. If sand erodes badly, try again, using lighter "rain" or spread a layer of pea gravel on top to hold the sand in place.

4. Every 2-3 minutes check the bottom of the box for evidence of color. After about five minutes, a plume of color should begin to appear. Draw the shape of this plume, to scale, on the chalkboard.

5. Check the size and shape of the plume after 1/2 hour and draw the new plume, to scale, on the chalkboard. Discuss the results. The plume should be broad and fanlike, pointing to the source of contamination. Notice that the red and blue dye components of the grape drink mix separate. Why do you think this happens?



C) Investigation.

1. Tell students they will now have to use a chemical test to find the source of an invisible contaminant. Point out the boxes in which you've placed the lemonade mix. Explain that a lemonade "contaminant" has been put in a different location in each box and they will be using pH paper to find the plume of contamination. Lemonade is acidic and will lower the pH of water it encounters. It may be helpful to review the meaning of pH and the use of pH paper. Remind students that as acidity increases, pH decreases.

2. Work in small groups at the lemonade contaminant stations.

3. Lay a 6 inch strip of pH paper on a dry desk or counter. You may need to secure the paper to the desk or counter by placing a piece of tape at each end. Put a small drop of water on one end of the pH paper, note the color and record the

pH of the water on your activity sheet.

4. With a watering can, "rain" lightly on the upper end of each box so there's no runoff. Keep watering lightly for about 5 minutes. Wait 15 to 20 minutes.

5. Using a piece of plastic straw, remove a plug of sand (and water) from one of the locations indicated on the activity sheet diagram. Drop the wet sand on the pH paper. Note the color of the pH paper and determine the pH of the sample. If the sample is more acidic (has a lower pH) than tap water, place a "+" on that location on your activity sheet. If the acidity is the same or lower (pH same or higher), place a "-" at that location on your activity sheet. Rinse the straw.

7. Take a total of 12 "test well" samples from the locations shown on the diagram, rinsing the straw after each sample. Determine the pH of each sample and record a "+" or "-" on your activity sheet at each location.

8. Complete the activity sheet and discuss your results.

- ❖ What makes a contaminant move from where it is buried?
- ❖ What is a "plume of contamination?"
- ❖ What are some real contaminants that could be seen, smelled or tasted if they got into groundwater?
- ❖ What are some real contaminants that could not be seen if they got into groundwater?
- ❖ In the real world, what factors underground might influence the movement of contaminants?

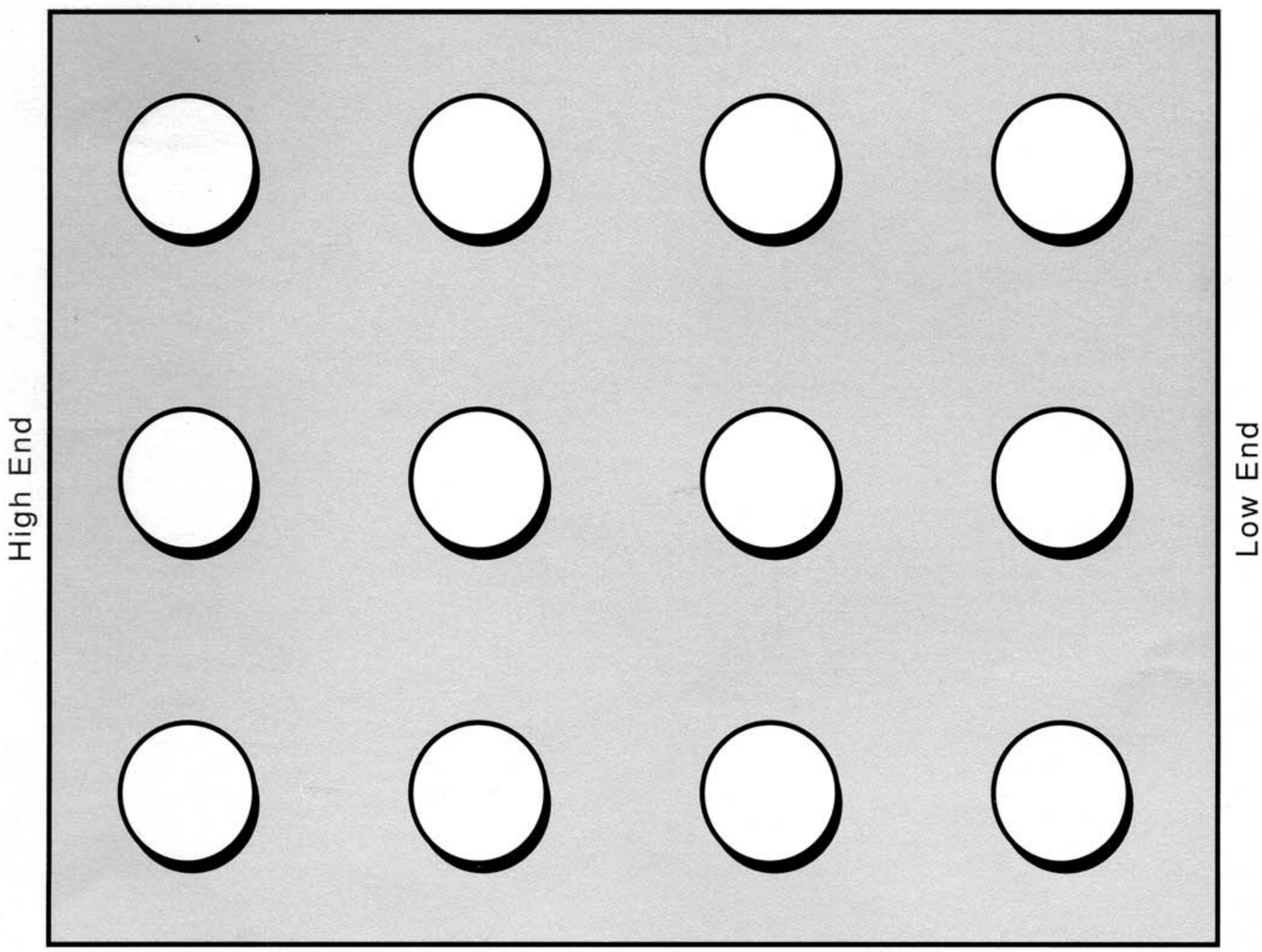
Going beyond:

1. Research and report on the types and effects of groundwater contamination from various sources in your area (e.g. private homes, schools, farms, landfills, gasoline stations, mine sites, septic tanks, industries, businesses, salt stockpiles, etc.).

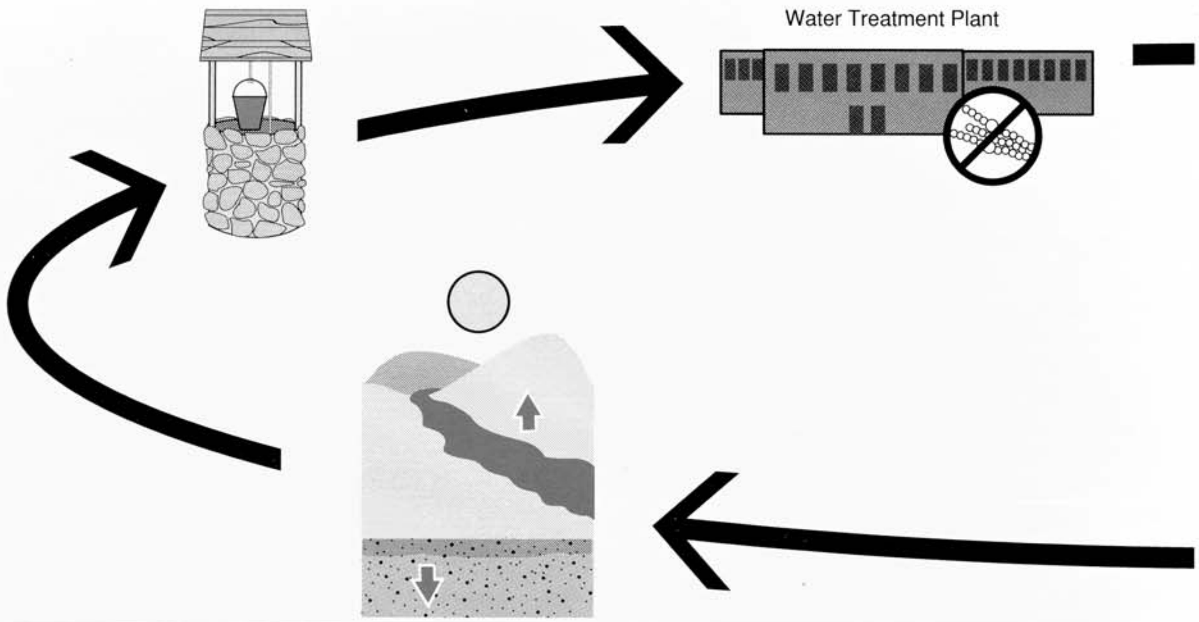
2. Research and report on the effects contaminated groundwater may have on human health. Have a physician or public health official visit and discuss the topic.

3. Investigate bottled drinking water. Where does it come from? How much does it cost? What does the company do to insure that it is safe for human consumption? What regulations govern the quality of bottled water?

Adapted from: ***Groundwater Quality Protection in Oakland County****. 1984. The East Michigan Environmental Action Council.*



Household Water



Where Does it Come From?...Where Does it Go?

Goals: To help students become aware of where their community's water comes from, how it is obtained and how it is treated before use by investigating the operation of a local water treatment facility. To help students understand where wastewater goes and how it must be treated by visiting a local wastewater treatment facility.

Subjects: Science, Health, Home Economics

DPI Objectives: SC: D1-D4

EH: A2, A3, B1-B4, C1-C4, C6

SS: B1-B3

Grades: 6-9

Materials:

❖ pencils and paper

Background: Have you ever wondered where the water comes from when you turn on your tap or where it goes after it drains from your bathtub? Water for most urban and suburban areas in Wisconsin comes from city or town wells that tap an underlying aquifer. *Groundwater* from these wells passes through a water treatment facility on the way to our homes and through a wastewater treatment facility after draining from our sinks, bathtubs and toilets.

The following field trips (or guest speakers) can help students understand the workings of these facilities and encourage them to think about where their water comes from, how it is changed as it passes through their homes and how it must be treated before it is allowed to return to the groundwater supply.

Procedure:

A) Investigate a water treatment facility.

1. Contact your municipal water treatment facility and obtain permission to visit it. Arrange with the manager or other resource person to guide your trip and be available to answer questions. If a field trip is not possible, arrange for a water treatment specialist to speak to your class.

2. Before visiting the water treatment plant or having a guest speaker, develop a list of questions you would like answered. Send the list to the guide or guest speaker in advance so he/she can prepare responses. Questions to consider include:

❖ From what aquifer(s) does your school or municipality get its water?

❖ What is the extent (area), boundaries and depth of the aquifer?

❖ What geological materials make up the aquifer?

❖ How many wells does your school or community use? Where are they ? How deep are they? How much water can they pump per minute/hour/day? When were they installed?

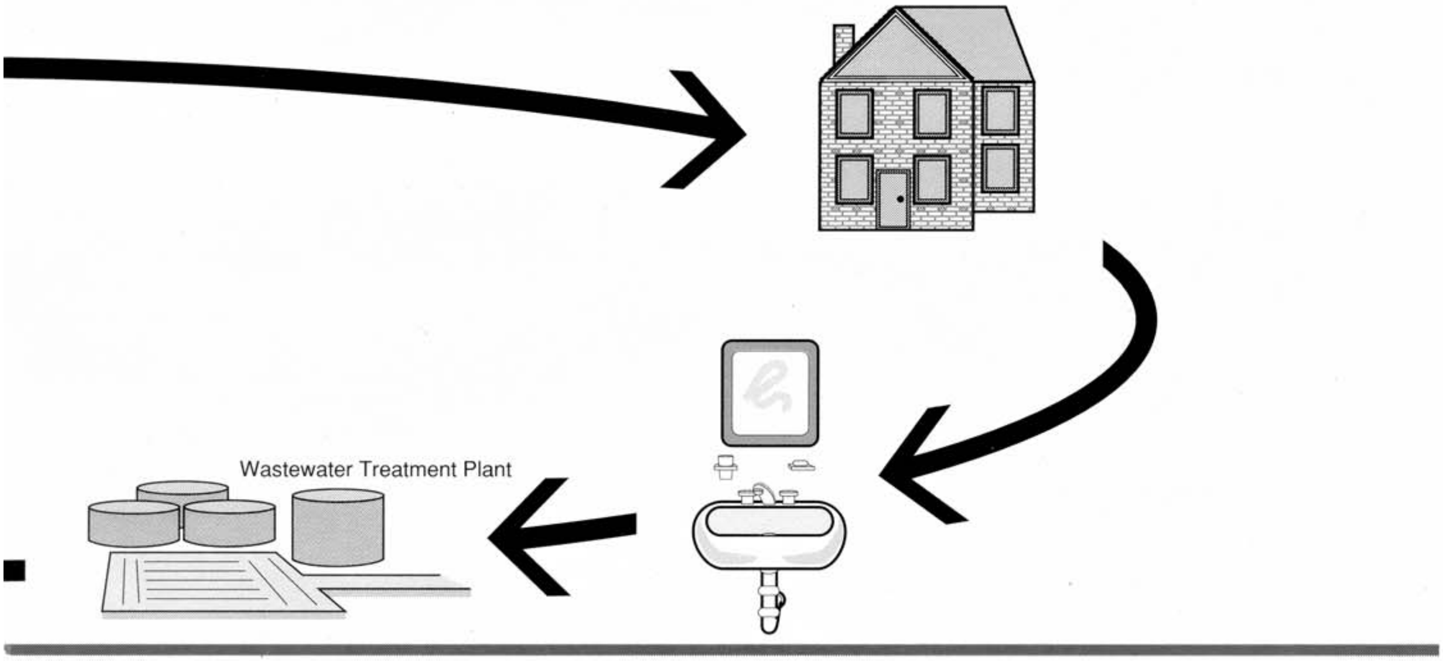
❖ What is a "cone of depression?" What is the extent of the cone of depression surrounding the well(s)? How does the cone of depression affect groundwater movement in the area?

❖ What time of the day, year, does the system pump the most water? Why?

❖ What is the natural chemical composition of the water before it is treated? How does the natural chemical composition compare with other wells around the state?

❖ How is water transported from the treatment plant to homes and businesses?

❖ Does the municipality have an adequate water supply for future needs?



❖ Are there any present or potential sources of contamination to the well(s)?

❖ What does the treatment plant do to insure that the water is safe to drink? What treatment methods are used?

❖ Is your community planning to drill new wells in the near future? If so, how much will it cost? Who will pay?

❖ How are local households charged for the water they use? (Do all local homes have water meters?)

❖ Does the price per gallon of water increase, decrease or stay the same as the amount used goes up? Does this pricing system encourage conservation?

❖ Does your community encourage water conservation in any other way?

3. Ask students to draw a diagram of a water treatment plant (including wells and aquifers) and describe how the facility works.

B) Investigate a wastewater treatment facility.

1. Arrange field trip or guest speaker as outlined in part A.

2. Prepare and send a list of questions you would like answered to the field trip guide or guest speaker so he/she can prepare responses. Questions to consider include:

❖ What household water passes through a wastewater treatment plant?

❖ Are all the homes in the community connected to a wastewater treatment facility?

❖ How does a wastewater treatment facility work?

❖ What is "grey-water?"

❖ What is "sludge?" Is it solid or hazardous waste? Why?

❖ What is done with sludge from the treatment plant?

❖ How much wastewater is processed each day?

❖ What training does the operator have?

❖ What happened to wastewater before the treatment plant was built?

❖ How might wastewater affect groundwater?

❖ What household materials should not be washed down the drain? Why?

❖ Can household chemicals affect bacteria at the wastewater treatment facility?

❖ How might sludge affect groundwater?

❖ What is the difference between a septic system and a wastewater treatment plant?

❖ How might a septic system affect groundwater?

3. Ask students to draw a diagram of a wastewater treatment plant and describe how the facility works.

Adapted from: ***Groundwater Study Guide****. 1984. Wisconsin Department of Natural Resources, Bureau of Information and Education.*

How Septic Systems Work

Goals: To have students understand how a septic system works. To help students realize how septic systems, if improperly cared for or placed in an unsuitable location can pollute groundwater.

Subjects: Science, Health, Home Economics

DPI Objectives: SC: A1-A3, D1, D2

EH: A1-A3, B1, B3, B4, C1, C3, C4

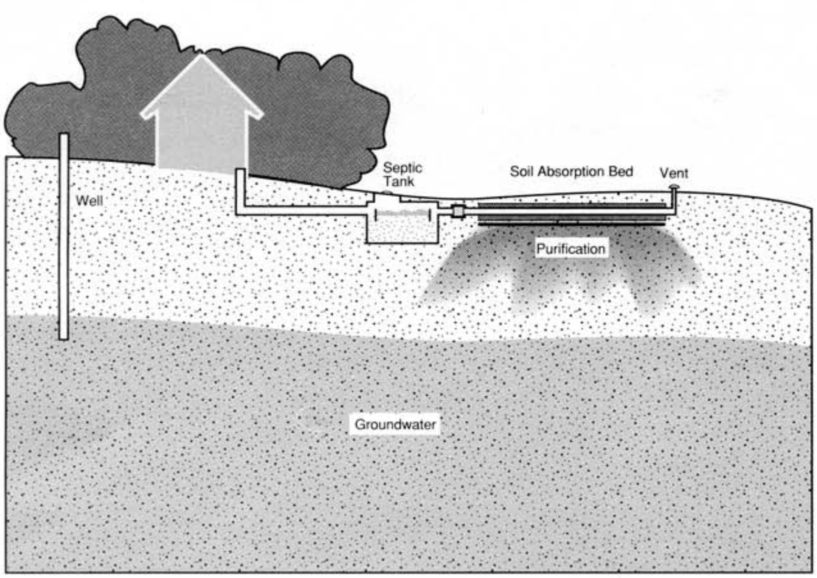
SS: A1, B1-B3, C1, C3

Grades: 6-9

Materials:

- 6 Steps to a Successful Septic Tank System overhead*
- The Septic Tank at Work overhead*
- How Septic Systems Work activity sheet
- for each group of 2-4 students:
  - one small (6-8 oz.) glass jar or beaker
  - one large (12 oz.) glass jar or beaker
  - sand
  - paper towel
  - potting soil
  - green food coloring
  - flexible straws
  - small pieces of white paper (e.g. holes from paper punch)

* masters provided



Background: Many rural homes use septic tank systems for disposal of wastewater from sinks, bathtubs and toilets. There are two parts to a septic system: a settling/storage container (septic tank) and a filtering area (soil absorption or leaching field). Both parts of this system are essential for proper wastewater disposal.

The main purpose of the settling tank is to protect the soil absorption field. Inside the settling tank, solids settle and form a sludge layer on the bottom and floating materials accumulate in a scum layer at the water surface. Clarified wastewater leaves the settling tank through a submerged outlet. The scum and sludge are left behind. This is important because scum and sludge can clog soil pores and cause the leach field to fail.

Bacteria in the septic tank helps to break down the scum and sludge that remains. Decomposition of these layers is slow, so scum and sludge gradually build up and must be removed periodically. Using kitchen garbage disposals increases the amount of solids in wastewater and speeds up sludge accumulation. (Composting vegetable matter instead of putting it down the garbage disposal keeps extra solids out of septic systems and also provides good fertilizer for flowerbeds and gardens.)

The soil absorption or leaching field does two things. It slowly disposes of wastewater below the surface of the ground, and it filters out harmful bacteria and many chemical contaminants before they reach groundwater.

Watertight pipes transport wastewater from the septic tank to the absorption field. In the absorption field, the water is divided among several trenches. Perforated, rigid plastic pipe or agricultural drain tile distributes the water throughout the trenches. A gravel bed below the distribution pipes temporarily stores the wastewater until it is absorbed by soil surrounding the trench.

Septic systems can pollute groundwater if the capacity of the surrounding soil to filter the wastewater is exceeded or if the underlying soils are very permeable, allowing contaminants to move rapidly to the water table before filtering is complete. Groundwater may also become contaminated if chemicals that are not decomposed by soil bacteria are dumped down sinks or toilets.

Adequate spacing of homes and proper planning, design, construction and maintenance of septic systems is the best insurance against groundwater contamination by household wastewater. Planners must consider the location of buildings, water supplies and soil characteristics. They must also decide how large a septic tank and absorption field is needed.

Proper maintenance of the system includes periodic pumping of sludge from the septic tank. Depending on the size of the tank and the number of persons in the household, cleaning may be needed as often as every two years or as seldom as every ten years, but tanks should be checked yearly.

Procedure:

A) Explanation.

1. Using the overheads, briefly discuss where wastewater goes in rural areas. Explain how a septic system works.

B) Investigation.

1. Work in small groups. Prepare a "wastewater" sample—water, sand, bits of paper and 2-3 drops of green food coloring.

2. Construct a model septic tank system:

a) Label small jar or beaker "septic tank."

b) Pour a well-stirred sample of wastewater into the septic tank until it is about 3/4 full.

c) Allow the sample to settle. Make observations.

d) Prepare a "leach field" as follows: Add alternating layers of sand and potting soil, separated by paper towels to the large jar or beaker. Wet the leach field.

e) Set the septic tank on a book or other riser. Place the leach field directly below the septic tank. Bend the flexible straw and fill it with water. Place fingers over both ends to keep the water in. After the wastewater has settled, connect the septic tank with the leach field as shown. Keep fingers over the ends of the straw until it is placed in the wastewater. This should create a siphon, allowing wastewater to flow onto the leach field. (It may be helpful to demonstrate this step for your students.) Observe the action of wastewater on the leach field.

3. Discuss your results:

❖ What settled to the bottom of the septic tank? What stayed on the surface?

❖ What was filtered out of the wastewater as it passed through the leach field? What was not? As in your septic system model, some components of wastewater (such as bacteria) are usually filtered out by soil. Other components (such as chloride, nitrates and volatile organic chemicals) are not effectively filtered and may be carried into groundwater.

❖ How did the green dye change as it passed through the leach field soil layers? Why?

4. Interview a friend or relative who has a septic tank system (instead of being connected to a municipal wastewater treatment plant). Find answers to the following questions:

❖ Where does their water come from?

❖ If their water is from a private well, how far is the septic tank from their well?

❖ How far is the absorption field from their well?

❖ How far is their house from the septic tank?

❖ How far is their house from the leach field?

❖ Refer to the table on the worksheet. Is there anything closer to the septic tank or absorption field than the recommended minimum separation distance? If so, circle the unit and record next to the table how close it is.

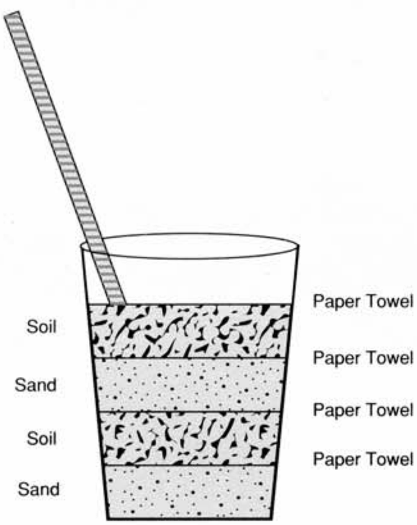
❖ What is one other factor (besides separation distance) to consider when planning a septic system?

Students may find that many people don't know the answers to these questions. Should they? Why is this important? Discuss.

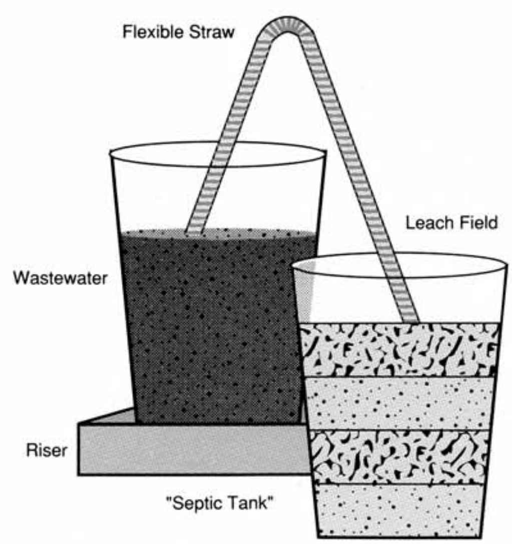
Going Beyond:

1. Investigate and compare different types of septic systems. Invite the county on-site waste disposal specialist to speak to your class. Ask him/her to bring diagrams of conventional and mound systems. Under what circumstances should a mound system be built? Are there other septic tank designs? When are they used?

Adapted from: ***Groundwater Resources and Educational Activities for Teaching****. 1989. Iowa Department of Natural Resources.*



"Leach Field"



"Leach Field"

Caution: This Product May be Hazardous to Your Health!

Goals: To teach students how to obtain information on use, storage, disposal, and hazards of household products by finding instructions and key words on product labels. To help students understand that many common household products can be dangerous groundwater contaminants if not used, stored and disposed in a safe manner. To have students realize that less harmful alternatives can be used in place of many household hazardous products.

Subjects: Science, Health, Home Economics, Environmental Science, Math

DPI Objectives: SC: A1-A3, D1-D3

EH: A1-A3, B1, B4, C1, C3-C5

SS: B3, C1, D1-D3

Grades: 6-9

This activity is divided into two parts: Part 1 is designed to teach students to read instructions and information on household chemical labels. In Part 2, students are asked to complete a home inventory of hazardous materials with the help of their parents.

Part 1: Reading Product Labels.

Materials:

- Letter to Parents handout (for Home Search activity)
- A Home Chemical Search activity sheet (for Home Search activity)
- Reading Product Labels activity sheet

Background: Many materials commonly found in our homes can be hazardous for children, adults and pets. The U.S. Environmental Protection Agency estimates that each home throws out an average of six pounds of hazardous waste every year. While six pounds may not seem like very much, it all adds up. A town of 10,000 homes can generate 60,000 pounds of hazardous waste in just one year! Take a quick inventory of materials you use and store in your kitchen, basement and garage. Many of the products you might find, including aerosol sprays, cleaners, insect repellants and poisons, motor vehicle products, paints, paint thinners, furniture strippers and fabric stain removers are considered hazardous. They should be used, stored and disposed of with care.

Chances are the only advice you receive for using and storing these products is from the label on the container. Unfortunately, many product labels contain little or no information for disposal of left over material or empty containers. If these products are poured or buried in the backyard or dumped into the drain or toilet they can soak through soils and reach groundwater (they can also run off into surface waters). Many products can also interfere with your wastewater treatment plant by killing bacteria essential for treating sewage.

If we read and follow product labels carefully, illness, death and environmental damage that can result from misused, or improperly disposed hazardous materials can be avoided.

Procedure:

1. Using the following information, discuss what "hazardous" means. Explain toxic, corrosive, reactive, and ignitable.

- Hazardous materials and wastes are chemical substances that can harm, contaminate or kill living organisms. Hazardous materials have one or more of the following characteristics:
- **Toxic**: Poisonous, potentially harmful to human health, can cause cancer and/or birth defects, and can contaminate, harm or kill fish and wildlife.
- **Corrosive**: A substance that can corrode storage containers or damage human tissue if touched.
- **Reactive**: An unstable substance that can react if exposed to heat, shock, air or water. Reactions include explosions.
- **Ignitable**: A substance that can explode, catch fire or emit toxic gases or fumes into the environment.

2. Generate a list of hazardous materials from each category that might be found in the home. How do people know how to use, store and dispose of these materials?

3. Complete the "Reading Labels" activity sheet.

4. Discuss your answers.

- How might this product find its way into groundwater?

❖ What effects might contamination have on people drinking the water?

❖ Can you think of any alternatives to using the product?

5. Distribute the "Household Chemical Search" activity sheet and the "Letter to Parents." Ask students to fill out only the first two columns on the activity sheet (i.e. mark with an X if the product is found and estimate the amount of chemical present). Go through the list of substances and possible locations in the home. Ask students if they have questions about any of the substances.

This activity can be an excellent opportunity for students and their parents to learn about hazardous chemicals together. **Remind students to ask their parents for help filling out the worksheet, to avoid touching any of the substances, to read container labels carefully and to wash their hands when through.** Students should have 1-2 days to complete the inventory.

You might also investigate hazardous materials in your school by conducting a hazardous chemical search of your science room or cleaning supply closet!

Adapted from: ***Groundwater Quality Protection in Oakland County: A Sourcebook for Teachers****. 1984. The East Michigan Environmental Action Council.*

Part 2: A Home Chemical Search

Materials:

- ❖ Household Hazardous Waste Wheel patterns and directions *
- ❖ Can Some of Your Household Products Harm You? handout
- ❖ Completed Home Chemical Search activity sheet
- ❖ glue
- ❖ manila folders (2 per student)
- ❖ brads
- ❖ scissors
- ❖ 1 per student
- * Commercial "Household Hazardous Waste Wheels" are also available. See Resources—Additional Educational Materials.

Procedure:

1. Distribute "Household Hazardous Waste Wheel" patterns, directions and materials. Construct Household Hazardous Waste Wheels (follow directions printed on the wheel). When the wheels are complete, demonstrate how to use them. It would be helpful to have some examples of hazardous household products in the room.

2. Work in small groups. Using the "Can Some of Your Household Products Harm You?" handout, rate the toxicity of the products found in your homes. Ratings are 1-6, with 1 representing the least toxic materials and 6 the most toxic. Record your ratings on the "Home Chemical Search" activity sheet.

3. Calculate the total quantity of substances listed in each category (1-6) for your group. Using the Household Hazardous Waste Wheels, list directions for disposing of all products which are at least "very toxic" (a toxicity rating of 4 or greater). For all products which are at least "very toxic", also list at least one viable alternative to using the product.

4. Discuss the completed activity sheets.

❖ What kinds of products were found in each toxicity category?

❖ What was the total quantity of hazardous material in each category for your class?

❖ What makes these products hazardous (e.g. toxic, corrosive, reactive, flammable)?

❖ What alternatives were suggested?

❖ How viable are these alternatives? Discuss advantages and disadvantages of using the alternatives and of using the products with a toxicity rating of 4 or greater.

❖ Which products represent "needs" and which represent "wants?"

❖ Using your homes as the average, estimate how much hazardous waste would be found in your community, in the state and in the nation.

❖ How might these products enter groundwater?

❖ How should these materials be disposed?

❖ What kinds of warnings did you find on the containers? How can you tell if a product is considered hazardous?

Going beyond:

1. Research the disposal of household hazardous materials in your area. Does your county, city or town offer a Clean Sweep? If so, when is it? What products should be taken there for disposal? How much hazardous waste is collected at the Clean Sweep each year? Does your community have a waste oil disposal facility? How much waste oil is collected there each year? What is done with the waste oil? Do people in your community know that these services exist? Do most people use them? If not, what do they do with their household hazardous waste? Your city/county Health Department should be able to provide information on household hazardous waste disposal programs.

Adapted from: ***Groundwater Quality Protection in Oakland County: A Sourcebook for Teachers****. 1984. The East Michigan Environmental Action Council.*

Many counties, cities and towns offer a "Clean Sweep." This is an opportunity for home owners to bring household hazardous materials to a central location for safe disposal. To find out about Clean Sweep programs in your area, contact your city or county health department.

Resource Protection, Value and Conflict

It'll Go With the Flow...

Goals: To teach students how to construct a water table elevation contour map. To help students understand how such maps can be used to determine general groundwater flow patterns. To allow students to evaluate a hypothetical landfill site based on the direction of groundwater flow.

Subjects: Science, Health, Math, Environmental Science

DPI Objectives: SC: A1-A3, B3, D1

EH: A3, B3, B4, C1

SS: A1, B3, D3

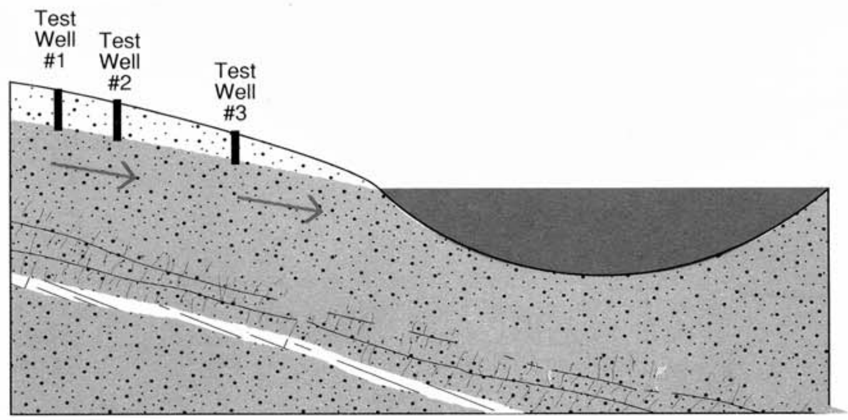
Grades: 7-9

Materials:

- It'll Go With the Flow activity sheet
- It'll Go With the Flow teachers key
- rulers
- pencils
- book and a marble for demonstration (optional)

Background: Groundwater usually flows in the same direction as the land slopes, often toward a nearby lake or stream. Many factors, such as rate of percolation from the surface and pumping from wells, can influence the direction and rate of groundwater flow, but it is possible to get an idea of how groundwater is moving in a given area by determining the slope or "plane" of the water table. To do this, at least three monitoring *wells* must be installed (three points determine a plane). By measuring the "static water level" (SWL), or elevation of the water table above sea level, we can estimate how groundwater will flow at a certain location.

Groundwater flows from areas of high static water levels to areas of low static water levels. This can be illustrated using a book and a marble. The marble will roll off the book in the direction of the slope and the speed of the marble will be determined by the steepness of the slope. Groundwater moves in much the same way.



It is important to consider the direction and rate of groundwater flow when planning land development to avoid potential contamination problems. Using static water level data, students will be asked to determine the general direction and relative rate of groundwater flow on a given map, and evaluate a proposed landfill site on the basis of this information.

Procedure:

A) Determine the slope of the water table and the direction of groundwater flow. The activity sheet gives land elevation/depth to water table. Ask students to subtract depth to water table from land elevation to get static water levels. Mark SWL's on activity sheet next to each well. Remind students that SWL's are height above sea level not depth from the land surface. Point out that the water table generally follows the contour of the land surface.

Construct contour lines by doing the following for each adjacent pair of wells:

1. Draw a line between the two wells. Measure the length of the line.

2. Subtract the smaller of the two SWL's from the larger. This is the difference in water table elevation (in feet) between these two wells.

3. Divide the line between the two wells into units representing 10 ft. intervals.

   a) Calculate the number of subdivisions needed by dividing the difference in water table elevations by 10.

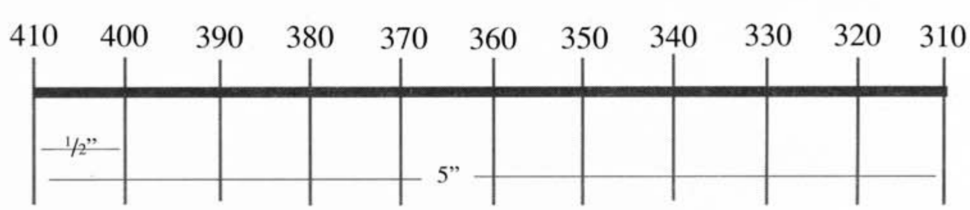
   b) Calculate the distance between subdivisions by dividing the distance between the wells by the number of subdivisions needed (see example).

4. Label each subdivision mark with the appropriate SWL as in example.

Example:

Distance between wells = 5 inches

SWL A = 410 ft. SWL B = 310 ft.



SWL difference: 410-310 = 100 ft.

Number of subdivisions: 100 ft./10 ft. intervals = 10

Distance between subdivisions: 5 inches/10 subdivisions = 1/2 inch per subdivision

5. Repeat steps 1-4 for each pair of adjacent wells.

6. Connect equivalent SWL's with light dashed pencil lines. These lines represent the contour of the water table elevation. (The lines are analogous to contour lines on a topographic map which connect equivalent land elevations.)

7. After all contour lines have been drawn, round sharp "corners" and draw solid lines over the original dashed lines. The groundwater flow at any point on your maps is perpendicular to the contour lines at that location. (See Teacher's Key)

B) Evaluate the proposed landfill site, marked "☆ ," using groundwater flow information from your contour maps.

1. Write a paragraph evaluating the proposed landfill site based on groundwater flow at "☆." (Note locations of the private wells.) If you think that locating the landfill at "☆" is not advisable, suggest two locations that might be better suited for a landfill. Support your choices by comparing rate and direction of groundwater movement at your proposed sites with that at "☆."

C) Discuss your findings.

❖ What is "static water level?" How is it different from water table depth?

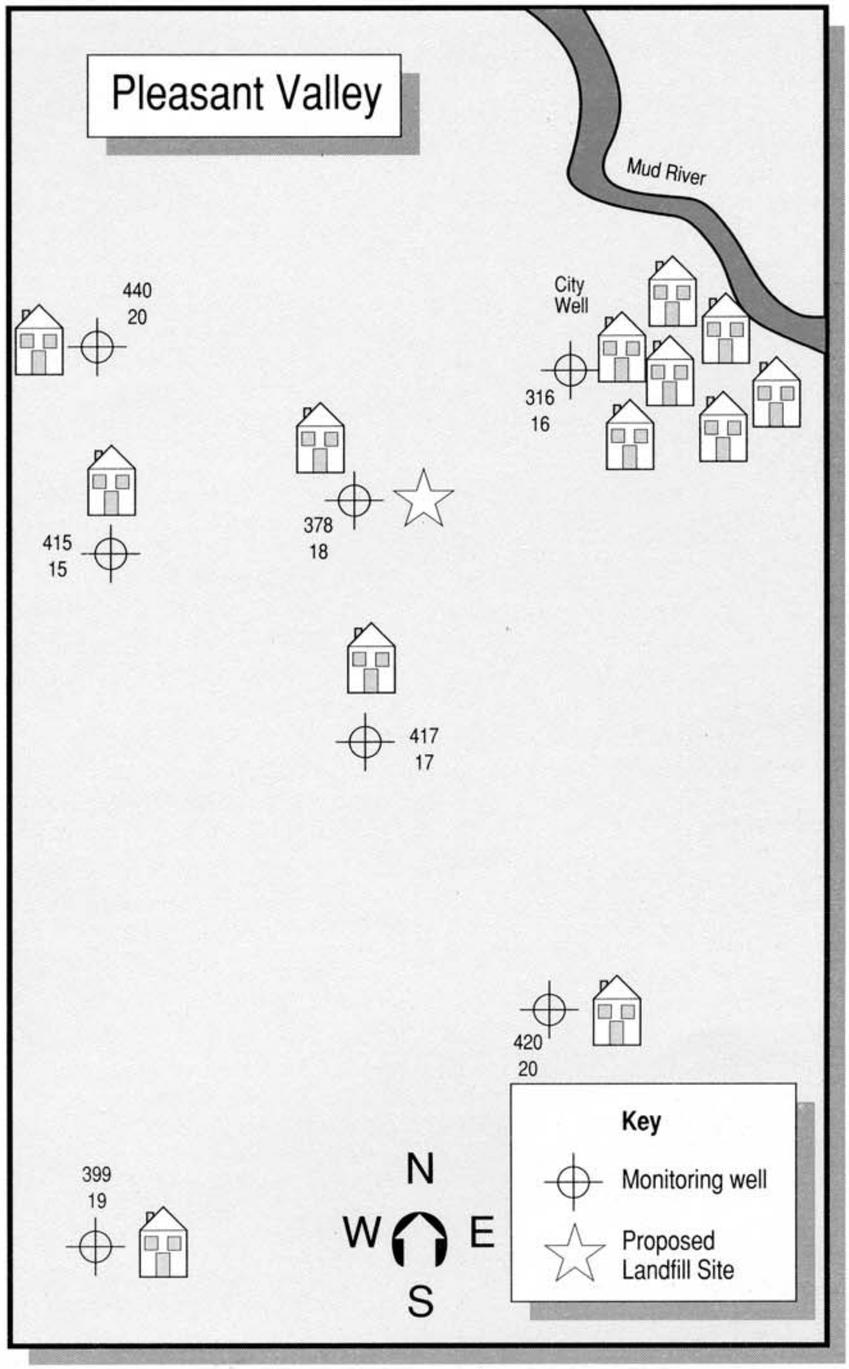
❖ How are SWL's used to determine the slope or plane of the water table? How does the plane of the water table affect groundwater flow (direction and rate)? What other factors might influence groundwater flow?

❖ What do the contour lines on your map show?

❖ In what general direction does groundwater flow in Pleasant Valley?

❖ Can we make assumptions about the speed of groundwater movement at certain locations?

❖ Would the contour lines change if you had SWL information from more wells? Fewer wells?



❖ What is the level of Mud River as it passes by town?

❖ Is "X" a good location for the landfill? Why?

❖ Can you suggest better locations for the landfill, based on groundwater flow? If so, why do you think these sites are better than "X"?

Going Beyond:

1. Conduct a hearing to decide where to locate a landfill in your community. Take on roles of people involved in making the decision: local landowners, politicians, industry representatives, geologists, environmentalists, waste managers and others. The Groundwater Susceptibility Map and topographic maps of your area may be helpful.

Adapted from: ***Groundwater: Michigan's Hidden Resource, Workbook.*** *1989. Michigan Department of Natural Resources.*

What if Water Cost as Much as Gasoline?

Goals: To have students understand that as a resource becomes scarce, the price we are willing to pay for that resource increases (i.e. understand the general concept of supply and demand). To help students realize that as a resource becomes more expensive, we often find ways to conserve that resource.

Subjects: Science, Math, Home Economics, Social Studies

DPI Objectives: SC: A1-A3, B6, D1-D4

EH: A2

SS: A1, B1-B3, C1, D3

Grades: 6-9

Materials:

- What if Water Cost as Much as Gasoline? activity sheet
- play money (master provided)
- legal size envelope for each student

Background: At one time energy—gasoline and fuel oil—was so inexpensive that people did little to conserve it. People drove as much as they wanted, energy-efficient cars were less of a concern and homes were built with very little insulation. Today water is relatively inexpensive. Few people try to conserve water just as few people conserved gasoline or fuel oil when they were less expensive. This activity is designed to help students begin thinking about the value of water.

Procedure:

1. Interview a grandparent or older neighbor. Ask about the present and past price of gasoline, fuel oil and water. Ask also about conservation of these resources. Questions should include:

- What is the lowest price you remember paying for gasoline? Did you conserve gasoline then?
- What price do you pay for gasoline today? Do you try to conserve it now? If so, how?
- When you began driving, what would your response have been if someone would have told you that the price of gas would reach more than $1.00/gallon in the 1980's?

- Do you remember when it was less expensive to heat your home? Did you conserve energy then? How?
- How much does it cost to heat your home in the winter today? Do you try to conserve energy now? How?
- How much water do you use in your home in a year? Do you try to conserve water? Why? How?
- Do you work harder to conserve energy or water? Why?

2. Discuss your findings.

3. Ask students to imagine they are taking a trip into the future over a specified weekend. Water costs the same as the current price of gasoline (record current price on activity sheet master before photocopying or write $1.00 on sheet to make calculations easier). They will have to purchase all the water they use in a weekend by placing "money" in an envelope. (Make copies of money master sheet.)

Since some people have more money than others, some students should be given more money than others. Randomly give students $30, $40, $50. Students should also be given the "Sale on Water" activity sheet to record the water they use. Remind them to estimate the amount of water used on their behalf when a parent does laundry or prepares a meal (e.g. wash 4 loads of laundry, 4 people in family, assume that the water for one load was used on the behalf on the student).

Each time water is used, calculate the cost and deposit money in the envelope.

4. Discuss your results.

- Who used the least water? Who used the most? What accounted for the difference?
- Was it easy to live within your water budget?
- Did you have to conserve water? Why? How did you try to conserve water?
- Should people try to conserve water? Why or why not?
- Should water cost so much that some people are forced to conserve it more than others?
- Making a natural resource expensive is one way to encourage people to conserve. What are other ways to encourage people to conserve natural resources?

  Examples:

  Education programs—try to teach people to conserve the resource

  Rationing programs—set strict limits on water use

  Tax credits and deductions—Provide economic incentives to conserve the resource

- Which methods to encourage conservation do you think would be most effective? Which are the most fair?
- Should people conserve water even if it's inexpensive? If so, why?

> "Water Wheels" with ideas for household water conservation may be ordered for this activity. See Resources—Additional Educational Materials.

Going Beyond:

1. As a class, compose and send a letter to a public works department in a dry western/southwestern city (e.g. Tucson, Santa Fe, Denver, Los Angeles or Las Vegas) to find out how they charge residents for water. Do they encourage conservation? If so, how?

Adapted from: ***Local Watershed Problem Studies****. 1981. Cooperative Educational Service Agency 16 and the Water Resources Center, University of Wisconsin, Madison.*

Rights or Fights

Goals: To help students understand the four basic doctrines of groundwater use law. To encourage students to consider the implications of the four groundwater doctrines by allowing them to act as a judge and use the doctrines to decide a historical groundwater case.

Subjects: Social Studies, Science

Grades: 9 (and up)

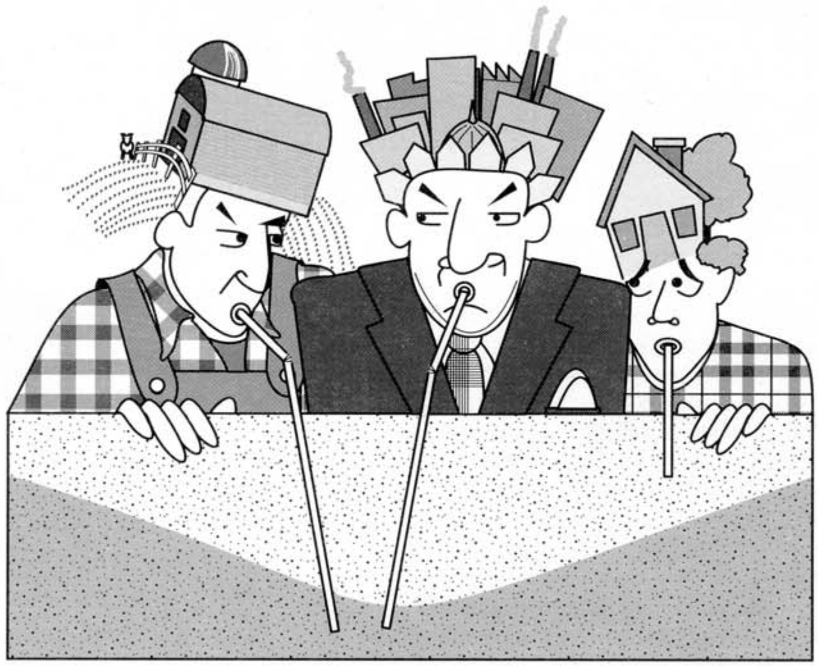
DPI Objectives: SC: D1-D5

EH: A1, A2, B4, C1, C3

SS: A1, B1-B3, C1, D1-D3

Materials:

- Rights or Fights activity sheet



Background: Who owns groundwater? Who has the right to use it? How much can they use? Should they be allowed to change its quality? Can water rights be sold? As with any limited resource, we must have rules and laws to regulate groundwater use and protect its quality. Making groundwater laws is not easy. Courts and law makers must consider competing uses, water availability and water quality. Laws must evolve as uses, availability and quality change.

Groundwater rights involve two separate issues, WATER USE (quantity) and WATER QUALITY. In Wisconsin, groundwater quality is generally covered by legislative law. Legislative law is created by the State's legislative or administrative processes. Legislative laws include constitutions, treaties, statutes, administrative rules and regulations, and ordinances.

Groundwater quantity laws, on the other hand, are generally based on "common law." Common law is law which is developed through court case decisions. A judge establishes societal values as law by issuing decisions in cases that he/she hears. Common law may change as societal values change. This activity focuses on the evolution of Wisconsin's groundwater common law.

Over time, four doctrines of groundwater use law have evolved in the United States. Each state treats groundwater conflicts differently, relying on one or more of the following doctrines as the basis for its groundwater use law.

1. **English Rule:**

Groundwater use is a property right. Under this doctrine, a land owner has the right to use the water under her land at any time and for any purpose. She may also sell or allow others to use her water. This rule grew out of the belief that groundwater movement could not be understood and that landowners couldn't anticipate the consequences of pumping groundwater.

2. **Reasonable Use Rule:**

Groundwater use is a property right. But water may only be used for "reasonable" purposes. A property owner may use the water on the land from which it came or elsewhere, as long as his use is reasonable in comparison to the water needs and uses of his neighbors.

3. **Correlative Rights Rule:**

All land owners in an area have a right to use groundwater. The amount of water each land owner can use depends on the amount of land she owns. She cannot pump more than her share of water, even for use on her own land if other water users don't have enough water to meet their needs.

4. **Appropriation Rule:**

Sometimes called the rule of "first in time, first in right." Groundwater rights under this doctrine are not connected to land ownership. A person has a right to use groundwater if he has obtained it and put it to a beneficial use such as irrigation, mining, manufacturing, power generation, raising fish, watering farm animals, household or recreational uses. (Water uses may be assigned priority.) Water may be used on the land from which it came or elsewhere. Appropriation rights may be sold or given to others.

Under the Appropriation Doctrine, in times of water shortage, those who have used the water longest (i.e. those who have the earliest "appropriation date") may use all the water they have used in the past and newcomers may be left with little or no water. If a person stops using his share of water for a beneficial purpose, he may lose the right to use the water at all.

With a better understanding of groundwater movement and the water cycle, there has been a general trend from viewing groundwater as **private property** to recognizing it as a valuable **public resource**. The two Wisconsin landmark cases used for this activity, Huber v. Merkel and State v. Michels Pipeline, illustrate this trend. Another recent trend in groundwater use law is increased legislation rather than a dependence on case law.

Until 1974, Wisconsin's groundwater law was based on the English Rule. In 1903, a Wisconsin Supreme Court decision (in Huber v. Merkel) established that a land owner has an absolute property right to use groundwater under his/her land. The judge determined that a land owner may use his water for any purpose, including malicious waste.

As you can probably imagine, the 1903 decision was heavily criticized, but the English Rule stood until 1974, when the State took Michels Pipeline Construction, Inc. to court for harming local wells and building foundations when they dewatered soil for construction of a sewage pipeline. The Court in State of Wisconsin v. Michels Pipeline determined that such injury could be considered a "public nuisance." The 1903 decision was overruled as the judge found in favor of the State on the basis of a Modified Reasonable Use Rule. This doctrine is the basis of Wisconsin's groundwater use common law today. (Huber v. Merkel and State v. Michels Pipeline are outlined in greater detail on Rights or Fights activity sheet.)

Groundwater use is still considered a property right under Wisconsin's Modified Reasonable Use Rule, but a landowner may withdraw and use groundwater only for beneficial purposes and only if pumping does not cause unreasonable harm to his/her neighbors. "Unreasonable" harm includes lowering the water table, reducing artesian pressure and direct effects on water levels of streams and lakes.

Procedure:

1. Explain the four doctrines of groundwater rights law.

2. Read aloud Huber v. Merkel from activity sheet. (It may be helpful to explain flowing artesian wells.)

3. Discuss Huber v. Merkel.

   ❖ Why did Mr. Huber take Mr. Merkel to court?

   ❖ What is a flowing artesian well?

   ❖ How did Mr. Merkel's actions affect neighboring wells?

   ❖ What did the State Supreme Court decide in this case?

   ❖ On what groundwater doctrine was The Court's decision based?

4. Read aloud State of Wisconsin v. Michels Pipeline Construction, Inc. from activity sheet.

5. Discuss State v. Michels Pipeline.

   ❖ Why did the State take Michels Pipeline Construction Co. to court?

   ❖ What did dewatering the soil do to local wells and properties?

   ❖ What did the State ask that the company do to correct this problem?

   ❖ What did the Court decide in this case?

   ❖ On the basis of what groundwater doctrine was this case decided?

   ❖ What is the difference between this doctrine and the one used to decide Huber v. Merkel? What are the similarities?

   ❖ How would this case have been decided on the basis of the old English Rule Doctrine?

   ❖ How did the State v. Michels Pipeline case change the course of groundwater use law in Wisconsin?

6. Ask students to imagine that they're on the 1903 Wisconsin Supreme Court. Work in small groups and assign a scenario (a-c on the activity sheet) to each group. Tell students that they are responsible for deciding Huber v. Merkel. Complete the appropriate section of your activity sheets.

7. As a class, complete scenario d.

8. Discuss your answers.

   ❖ How would the case have been decided using Wisconsin's Modified Reasonable Use Doctrine? The Correlative Rights Doctrine? The Appropriation Doctrine?

   ❖ Which doctrine do you think is the most fair for deciding scenario d? Why?

   ❖ Do you think water availability influences the groundwater doctrine followed by individual states? If so, how?

   ❖ In some states groundwater and surface water laws are based on different doctrines. What problems might result if a state used the Appropriation Doctrine for its surface water and the English Rule for its groundwater? (Hint: think about the water cycle!)

Going Beyond:

1. Invite an attorney or other Wisconsin water law expert to discuss laws pertaining to groundwater quality in Wisconsin. Discuss State of Wisconsin v. Michels Pipeline. What laws would the Court need to consider if the State's complaint was groundwater *contamination* by the construction company?

2. Wisconsin follows the modified Reasonable Use Doctrine. Research and report on a state that follows the English Rule, Appropriation or the Correlative Rights Doctrine. How is this state different from Wisconsin? What historical and/or environmental factors do you think influenced groundwater use laws in that state?

3. Collect newspaper and magazine articles on groundwater-related issues in Wisconsin. Using a map of the state, make a display of issues by location. Discuss related groundwater laws, personal costs, responsibility, solutions, etc.

4. Collect newspaper and magazine articles about groundwater-related issues in a western state (e.g. California or Colorado). Using a map of the state, make a display of issues by location. How are the problems similar to those in Wisconsin? How are they different? Compare personal costs, responsibility, solutions, etc.

5. Research and report on which governmental agencies (municipal, county, state, and federal) regulate and protect groundwater. How do these groups work together? Discuss roles that other groups play. (see *Groundwater Supplement* p. 18-19.)

6. Research and report on how water resources have influenced the history of your community. How has water helped your community develop? Has groundwater played a special role? Many areas of Wisconsin are known for having "healthful" spring water. Is part of your community's history related to spring water? How does your community feel about protecting groundwater?

7. Groundwater is important in the production and processing of many Wisconsin products such as cheese, beer and paper. Investigate some of these products. How much water do they use? How clean should the water be? Are there laws or regulations that govern the quality of the water they use?

Trouble in Paradise

Goals: To have students use information provided in this activity and what they have learned about groundwater movement in previous activities to determine the source of well contamination in the mythical town of Paradise. To allow students to consider the implications of water contamination and suggest solutions for Paradise's problem.

Subjects: Science, Health, Social Studies, Home Economics, Environmental Science

DPI Objectives: SC: A1-A3, B2, B3, B5, C3, C4, D1-D5

EH: A3, A4, B1, B2, B4, C1-C6

SS: A1, B2, B3, C1, D2, D3

Grades: 7-9 (and up)

Materials:

- Trouble in Paradise handout
- colored pencils—red, blue and green

Background: In this activity, wells in the mythical town of Paradise have been contaminated with *volatile organic compounds* (VOC's). *VOC's* are a group of commonly used chemicals that evaporate, or "volatilize" when exposed to air. Since they dissolve many other substances, VOC's are widely used as cleaning and liquifying agents in fuels, degreasers, solvents, cosmetics, polishes, drugs and dry cleaning solutions. VOC's are found at airports and service stations; machine, print and paint shops; electronics and chemical plants; dry cleaning establishments; and in household products. Two common VOC's, toluene and benzene, are referred to in this activity.

When VOC's are spilled or dumped, some will evaporate and some will soak into the ground. Once in the soil, VOC's can be carried deeper into the ground by percolating rainwater. If they reach the water table, VOC's can persist for years because the cool, dark, low-bacteria environment does not promote decomposition. If VOC's in groundwater migrate to nearby wells, they can end up in someone's drinking water.

Of 2,230 community wells sampled in Wisconsin between 1985 and 1988, 113 (5.1%) have shown the presence of at least one VOC. Some had only traces, one or two parts per billion. But 28 community wells exceeded State Health Advisory Levels for drinking water.

Some VOC's can harm the central nervous system, liver and kidney. For these types of health effects, researchers can determine a "no-effect level"—a maximum VOC dose that does not produce the toxic effect in experiments. This "no-effect level" is further reduced by a safety factor which ranges from one tenth to one thousandth (depending on the strength of scientific evidence). From this number State Health Advisory Levels and EPA Maximum Contaminant Levels are established. Some VOC's (such as benzene) are known or suspected carcinogens (cancer-causers). Health Advisory Levels and Maximum Contaminant Levels for carcinogens in drinking water are conservatively set so that lifetime consumption of the water will cause no more than 1 to 10 additional cancers for every million persons exposed.

Several factors influence a well's vulnerability to VOC contamination. One factor is the distance between the well and the source or sources of contamination. Another factor is time. Groundwater usually moves very slowly and it can sometimes take years for a spilled contaminant to reach nearby wells. The time and distance contaminants must travel are extremely important because many wells which presently show no contamination may eventually become contaminated by spills that have already occurred. In other words, we may not know the full effects of contamination we already have caused for many years to come. (see *Groundwater Supplement* pg. 17)

There are two options for dealing with VOC contamination. The well owner can either construct a new well or treat water from the contaminated one. Treatment of the well water has the benefit of removing contaminated water from the ground. Both options are expensive. Drilling a new municipal well can cost as much as $500,000; building a water treatment facility for a contaminated municipal well generally costs between $500,000 and $1 million.

Activity setting:

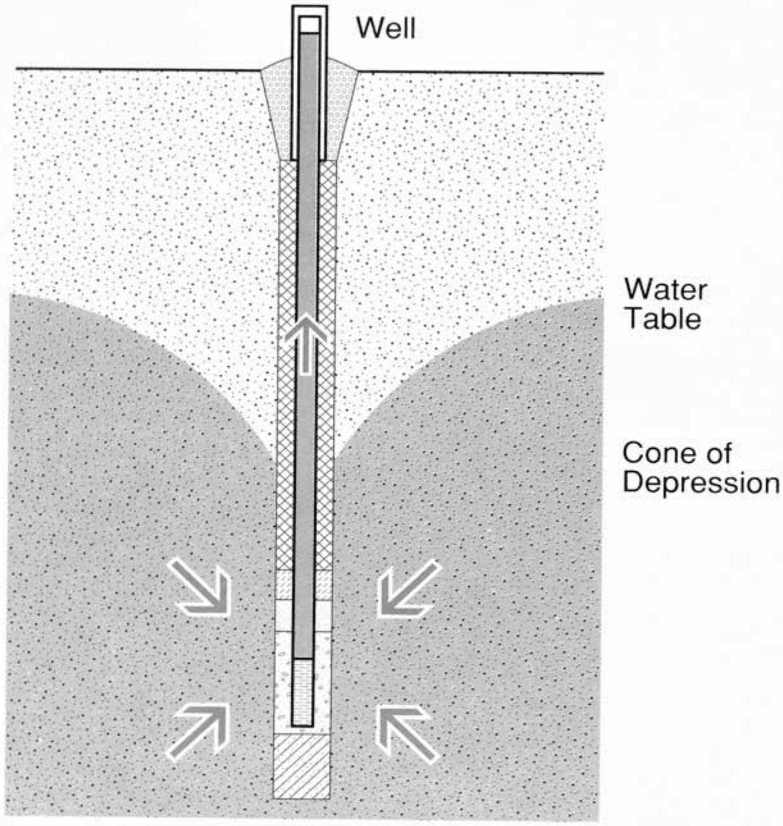
VOC contamination has occurred in "Paradise" and your students will be asked to determine where the VOC's came from and what should be done about the problem. The contamination was first noticed after the installation of a high capacity community well. Wells that draw a large volume of water can affect the direction and rate of groundwater flow by creating a "cone of depression." As groundwater is depleted under the well site, it is replaced by groundwater from soils surrounding the well. So even water that initially flowed away from the well can be drawn toward it as groundwater immediately under the well is removed.

The new municipal well in "Paradise" has created a cone of depression and is drawing water and the plume of VOC contamination toward itself. The source of contamination is the closed landfill at the Johnson farmsite which, while it operated, may have accepted wastes containing VOC's from local industries and households. This landfill was designed as a "natural attenuation" site, meaning that the landfill depended only on the characteristics of surrounding soils to contain and filter leachate from the waste deposited there. Today landfills must be lined with a layer of impermeable clay which helps to contain leachate. Modern waste disposal regulations also limit the type of wastes that can be deposited in a municipal landfill.

Procedure:

1. Using How Much is a Part per Billion? handout, discuss the idea of parts per billion, parts per million and parts per thousand. Explain that drinking water standards are often stated in parts per billion and that laboratory results are usually stated in ug/L. Point out that 1 ppb = 1 ug/L.

2. Tell students that the mythical town they will be investigating is based on several Wisconsin communities that actually experienced groundwater contamination. Explain what VOC's are and their many sources. Briefly discuss how Health Advisory Levels and Maximum Contaminant Levels are set.



3. Distribute "Trouble in Paradise" handouts. Have students read the case study.

4. Ask individual students to read aloud the problems on the activity sheet. Clarify any uncertainties about the problems.

5. Working in small groups, complete the activity sheet. Remind students that they will need to use the information given in the case study AND what they have learned in previous activities to answer the questions. It may be helpful to review the reading of topographic maps.

6. Using the completed worksheets, construct a master time line on the chalkboard. Discuss the time line and answers to activity sheet questions.

- In what general direction does groundwater flow in Paradise?
- What is the source of contamination? How do you know?
- Where would you place test wells to confirm the source of contamination?
- What is a plume of contamination?
- How did the shape of the plume of VOC contamination change? What caused it to change?
- Why did it take so long for the VOC's to move from their source into surrounding wells?
- Why did the contamination appear in the Hansens' well then seem to disappear?
- Why was there such a delay between the time that VOC's were first discovered in the Hansen's well and when city officials decided to take action?

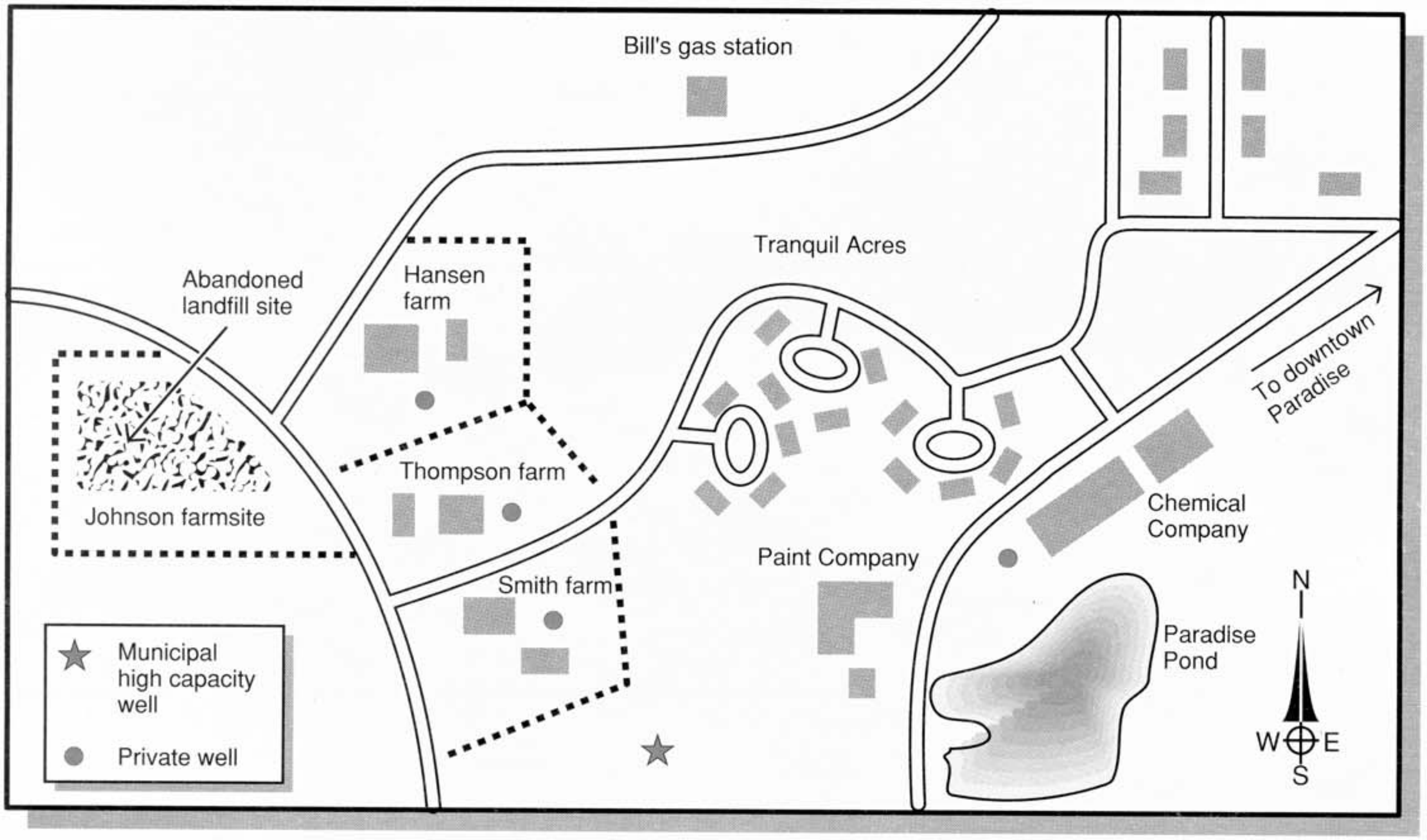
6. Discuss the implications of groundwater contamination in Paradise.

- What are VOC's used for?
- Who might have put materials containing VOC's in the landfill?
- When is groundwater "contaminated?" Is water that contains 200 ppb toluene considered contaminated? Is 200 ppb toluene considered unhealthy?
- Does contaminated necessarily mean unhealthy?
- Why do you think the Health Advisory Level for toluene is so much higher than the Maximum Contaminant Level for benzene?
- Who's to blame for the contamination?
- Who should pay to solve the problem?
- How did the citizens react to the contamination? Were their demands reasonable? What else could citizens do?
- How did the contamination affect private well owners?
- Should the Smiths' and Thompsons' well water be restored (either by construction of a new well or by treating water from existing wells)? If so, who should pay?
- Could the contamination affect the new community well?
- How long can Paradise's problem continue?
- If hazardous materials are removed from the landfill in Paradise, they may have to be moved to a hazardous waste landfill in another state. Is that fair? Who should pay to maintain and operate the disposal site?
- Could the contamination have been avoided? If so, how?
- What can Paradise do about the contamination now?
- Could your community have problems like this?
- How can your community help prevent groundwater contamination problems?

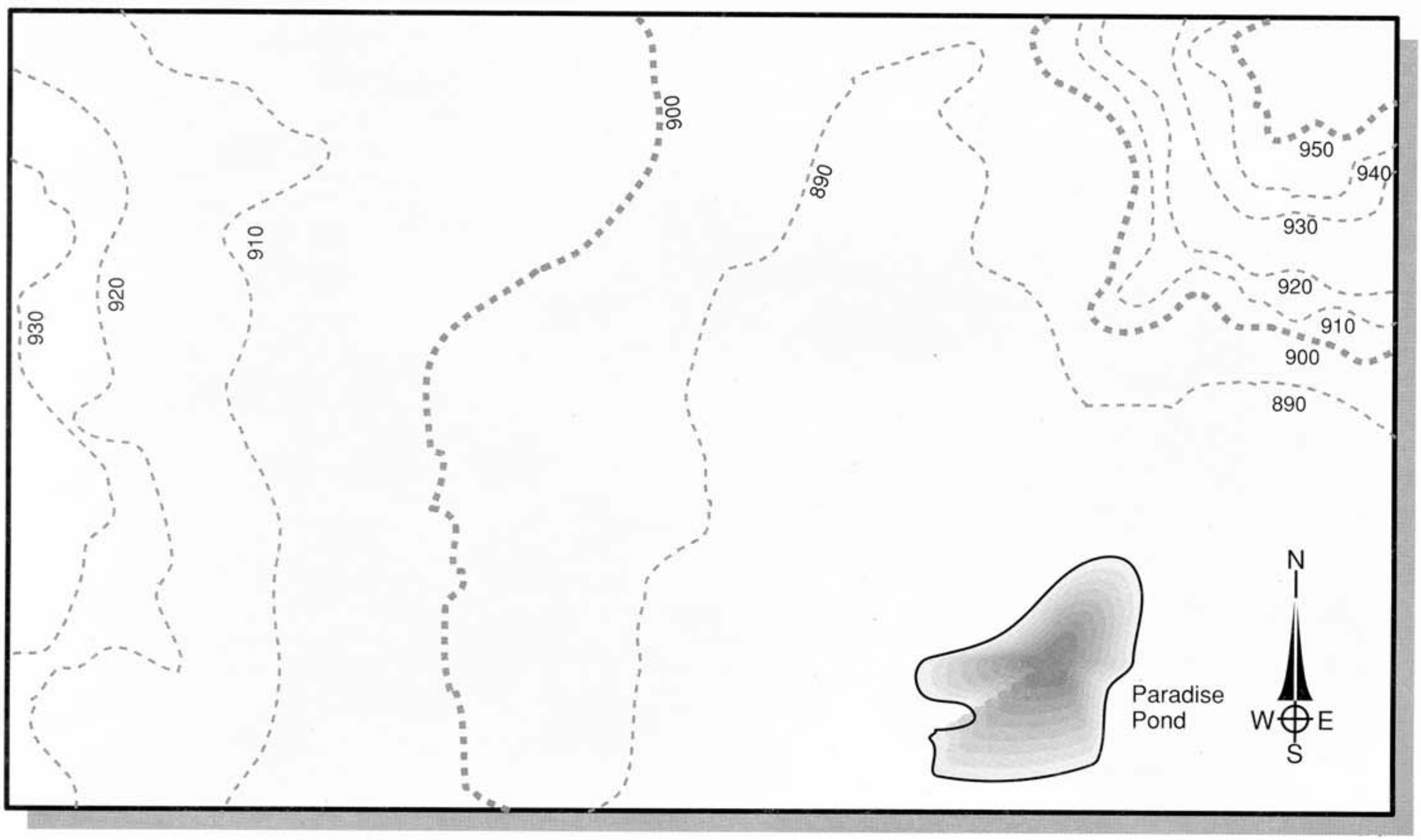
Going Beyond:

1. Using selected discussion questions as an outline, research and report on a groundwater contamination issue in your area.

Adapted from: ***Discovering Groundwater: A Supplementary Activities Guide for Upper Elementary Social Studies and Science Classes.*** *1984. Wisconsin Department of Natural Resources, Western District.*


Bill's gas station
Tranquil Acres
Abandoned landfill site
Hansen farm
Thompson farm
Johnson farmsite
Smith farm
Paint Company
Chemical Company
To downtown Paradise
Paradise Pond
Municipal high capacity well
Private well
N
W
E
S

Map A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Paradise Pond
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S

More Groundwater Activities!

❖ Make a collection of rocks and soils important in Wisconsin's aquifers. Make a display for your school or local library.

❖ Visit the State Laboratory of Hygiene in Madison or a private water testing laboratory (list of certified laboratories available from your local DNR office). What water tests are done at the laboratory? How much do the tests cost? How often are public wells tested? What tests are run on public water supplies? How often should private wells be tested? What tests are normally run on private water supplies? When is water considered "contaminated?" When is water considered "unhealthy?"

Private well owners should have their water tested for nitrates and coliform bacteria once a year.

Schools also must have their water tested regularly. Find out how often your school's water is tested. Who collects the water? What tests are run? Obtain a copy of the most recent test results and discuss.

❖ Collect and send a sample of your school's water to the State Lab of Hygiene for nitrate and bacteria testing. Each test costs $7.00 (total cost for bacteria and nitrates $14.00). For sample materials and instructions write to:

State Lab of Hygiene
465 Henry Mall
Madison, Wisconsin 53706

❖ Research and report on methemoglobenemia (blue baby syndrome) caused by high levels of nitrate in drinking water.

❖ Interview someone who has had a contaminated well. How did she/he determine that the well was contaminated? With what was the well contaminated? What was the source of contamination? Was the problem solved? If so, how?

❖ Visit a beverage or food-processing industry. What is produced at the site? Is water used in the production? How? Where does the water come from? How does the company insure that the water used is of good quality? Is wastewater produced? If so, what does it contain? How is it disposed of?

❖ Investigate your home or school's use of lawn chemicals. What chemicals are used? What do they do for the lawn? How are they stored? How are excess chemicals disposed of? Where do chemicals placed on lawns go when it rains? What effects might the chemicals have if they get into groundwater? Are there any alternatives to using lawn chemicals?

❖ Invite the county Extension agricultural agent to speak to your class about the advantages and disadvantages of insecticide and herbicide use. How should pesticides be used? What can be done to decrease the amount of chemical applied to a field or garden? Are there any pesticide contamination problems in your county? If so, what is being done about them? Can farmers eliminate the use of pesticides?

❖ Interview someone who farmed before the time of widespread use of nitrogen fertilizers. Find out about yields, prices, profits, conservation practices and groundwater concerns.

❖ Invite an organic gardener or farmer to speak to your class. What is organic farming? What alternatives to pesticides are used? How are natural pest controls, such as insect predators and companion planting used? How does not using pesticides affect crop yield? Crop appearance? Crop sales?

❖ Research and report on water needs of various agricultural crops grown in Wisconsin. How are these water needs met? What are some ways to irrigate farmland? Which methods cause the greatest and the least water loss (though runoff and evaporation)? What is the relationship between pesticide use and irrigation practices on groundwater?

❖ Interview a person involved in the production or distribution of pesticides or fertilizer. Ask about use, disposal, health, pollution, etc.

❖ Using newspapers and magazines, research groundwater contamination by landfills and dumps. Where did the contamination happen? Who was affected? What were the health consequences? Were there economic consequences? How was the source of contamination determined? Who was responsible for clean-up? How much will clean-up cost?

❖ Demonstrate that groundwater provides the base flow for rivers and streams. Visit a stream in early fall or late spring. What is the temperature of the stream? Why is the stream cold? Has it rained or snowed recently? Do you see water running off the land? If not, where do you think the water for the stream comes from?

❖ Research and report on the potential environmental and health effects of placing disposable diapers in municipal landfills. Compare the cost of using cloth diapers and a diaper service to that of using disposable diapers.

❖ Find out what materials are used to make paper, plastic and glass. What happens to these materials in a landfill? What effects might these materials, if leached from a landfill, have on groundwater?

❖ Make a magazine photo display of environmentally safe products sold in non-polluting packaging.

❖ Organize or participate in a recycling project. Report on how the recycled materials are used.

❖ Invent and demonstrate new uses for product packaging that you would normally just throw away.

❖ Write a list of rules and guidelines for your home for handling, storing and disposing of household hazardous materials.

❖ Interview a person who operates a gas station or other business that uses underground storage tanks. What is kept in the tanks? Could this material be harmful if it got into groundwater? How often are the tanks checked for leaks? How does the owner know if the tanks develop a leak? What is done if the tanks leak?

❖ Make a poster showing how your family or school can conserve water.

❖ Make a display of newspaper clippings involving groundwater issues for your school or local library.

Adapted from: ***Groundwater Study Guide*** *and* ***Groundwater Resources and Educational Activities for Teaching***.

Appendix

Selected Department of Public Instruction (DPI) objectives for Science, Health and Social Studies

Science Objectives:

A. Problem Solving

1. Ask questions
2. Collect data
3. Analyze data

B. Science Knowledge

1. Diversity
2. Change
3. Organization
4. Continuity
5. Interaction
6. Limitation

C. Nature of Science

1. Evolution of science
2. Milestones
3. Variety of methods
4. Assumptions

D. Science, Technology and Society

1. Societal needs
2. Personal needs
3. Attitudes and beliefs
4. Economics
5. Politics

Health Education (Environmental Health) Objectives:

A. Life Goals—the individual:

1. Obeys laws and regulations essential for the survival of humanity
2. Understands that all people have a responsibility to help conserve resources
3. Avoids actions that contribute to the deterioration of the environment
4. Utilizes agencies responsible for environmental protection

B. 6th Grade—students will be able to:

1. Describe ways in which improving the environment can enhance physical, mental, and social health
2. List the negative and positive environmental changes that may come about by the year 2000
3. Explain why sanitation is important to the nation's health
4. Explain the effects of environmental practices on well-being

C. 7-9th grade—students will be able to:

1. Describe the impact technology has had on the environment and human health
2. Identify local, state, and federal agencies that promote or affect environmental health
3. Discuss the individual's responsibility for preserving a healthy environment
4. Compare the origins and impact on well-being of various types of air, water, and land pollution
5. List potential environmental carcinogens
6. Know that over the past 100 years environmental control measures have greatly reduced human illness

Social Studies Objectives:

A. 6th grade—students will be able to:

1. Recognize that land forms, climate, and the availability of natural resources exert a powerful influence on the lifestyle, technology, and values of individuals and cultures

B. 7th grade—students will be able to:

1. Identify common problems, needs, and behaviors of people from similar and different environments
2. Explain the dependency of present and future generations upon the ecosystem
3. Engage in reasoned and responsive action in relation to humanity, the ecosystem, culture, and the social order

C. 8th grade—students will be able to:

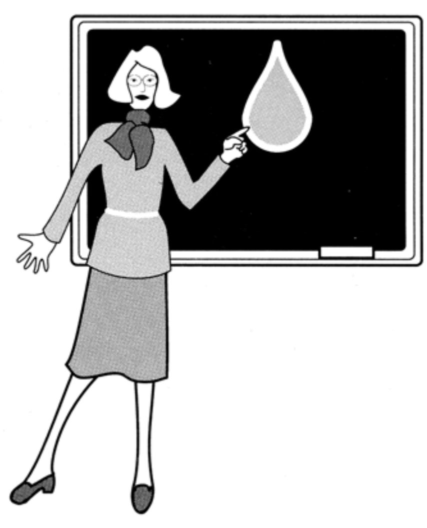
1. Develop and examine their own values and attitudes and those of others with respect to a commitment to democratic beliefs, personal responsibility and human freedom

D. 8th-9th grade—students will be able to:

1. Explain the principles of rule of law, legal limits of freedom, and majority rule with minority rights
2. Analyze a local community issue in order to identify the different value positions and make a personal choice on the issue
3. Demonstrate effective decision-making skills and apply them to important social problems

Other subjects to which groundwater activities may apply:

Math, Home Economics, Environmental Science, Agriculture Technology, English



Resources

Audio-Visual Materials

Groundwater: Wisconsin's Buried Treasure. (slide/tape) 1982. Available on loan from: Wisconsin Geological and Natural History Survey, 1815 University Avenue, Madison, Wisconsin 53706.

Wisconsin's Groundwater (16mm film). Rentals available from: Bureau of Audio Visual Instruction; P.O. Box 2093; Madison, WI 53701-2093; (608)262-3902; toll free in Wisconsin: 1-800-362-6888. BAVI has a large selection of groundwater-related films and videos. Write or call for a complete list. Many local and University libraries also carry this film. For purchase information contact: Department of Agricultural Journalism, University of Wisconsin-Madison, 440 Henry Mall, Madison, Wisconsin 53706; (608)262-1463.

RESOURCE PEOPLE:

Representatives from the following groups can explain their interest in groundwater and can often give insight into groundwater problems or issues of local interest. Contact with the community not only helps reinforce what is learned in the classroom, but helps develop concern and sustains the enthusiasm of students.

Before you involve a resource person in your class, discuss with him or her your objectives and what you expect from his/her visit.

- water chemists
- well drilling contractors (contact your local DNR office)
- pump dealers
- Department of Natural Resources environmental specialists (addresses of DNR district offices are found in the last section of this guide)
- municipal/county health or environmental specialists or county planners
- county University of Wisconsin-Extension resource or agricultural agents
- water treatment plant operators
- hydrologists, hydrogeologists and engineers—private industry and governmental agencies

ADDITIONAL FIELD TRIP IDEAS:

When planning a field trip, be sure to secure permission and discuss your activity with people at the site before your visit.

- municipal or county landfill site—possibly monitoring wells
- municipal water treatment plant—well water tower
- well drilling site (list available from local DNR office)
- State Laboratory of Hygiene (Madison, Wisconsin)
- private water testing laboratory (list of certified labs available from local DNR office)
- agricultural operation—irrigation with wells, integrated pest management
- water resource sites—springs, rivers, lakes, wetlands
- beverage or food processing industries
- rock exposures showing groundwater effects

GENERAL GROUNDWATER REFERENCES:

A Citizen's Handbook on Groundwater Protection. W. Gordon. Natural Resources Defense Council, New York, NY. 1984.

America's Priceless Groundwater Resource Fact and Fiction: The Story of Underground Water. 1977. Available from the National Water Well Association (see agencies and organizations).

Groundwater, A Non-technical Guide. J.Wilson Academy of Natural Sciences, Philadelphia, PA. 1982.

Groundwater Hydrology. H. Bower. McGraw-Hill Book Company, New York, NY. 1978

Groundwater and the Rural Homeowner. Single copies of booklet are free from: U.S. Geological Survey: Books and Open-File Reports Section, Box 25425, Denver, Colorado 80225.

Safe Water: A Fact Book on the Safe Drinking Water Act for Non-Community Systems. Available from the American Water Works Association (see agencies and organizations).

BULLETINS AVAILABLE FROM UW-EXTENSION OFFICES

(cost between $0.25 and $1.00 per bulletin, contact Extension office for current prices):

A7POG *Protecting Our Groundwater—A Grower's Guide*

G3399 *Maintaining Your Home Well Water System*

G3378 *Improving Your Drinking Water Quality*

G3339 *Drinking Water Contamination: Understanding the Risks*

G3338 *How Drinking Water Standards Are Established*

G3213 *Pesticides in Groundwater: How They Get There; What Happens to Them; How to Keep Them Out*

G3054 *Nitrate in Wisconsin's Groundwater: Sources and Concerns*

G2967 *Nonpoint Pollution: How Wisconsin Cities Affect Water Quality*

WI DNR PUBLICATIONS:

"Groundwater: Protecting Wisconsin's Buried Treasure" in *Wisconsin Natural Resources*. Vol. 13, No. 4. August 1989.

Special Recycling Edition. *Wisconsin Natural Resources*. Vol. 8, No. 4. July-August 1985.

"A Matter Of Chance, A Matter of Choice: Environmental Risk in Wisconsin" in *Wisconsin Natural Resources*. Vol. 13, No. 2. April 1989.

"The Cleanup Game" in *Wisconsin Natural Resources*, Vol. 13: No. 1. February 1989.

The following materials are available from the WI DNR Bureau of Information and Education (for a complete list write Wisconsin DNR, Bureau of Information and Education, P.O. Box 7921, Madison, WI 53707):

Hazardous Wastes in Your Home

Saving Wisconsin's Water

Water Conservation

Answers to Your Questions About Groundwater

Nitrates in Drinking Water

Pesticides in Drinking Water

Radium in Drinking Water

Volatile Organic Chemicals in Drinking Water

Lead in Drinking Water

Groundwater and Land Use in the Water Cycle—poster

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY PUBLICATIONS:

The Wisconsin Geological and Natural History Survey has a variety of inexpensive groundwater-related publications and maps. For a catalog of recent publications, write to 3817 Mineral Point Road; Madison, Wisconsin 53705.

AGENCIES AND ORGANIZATIONS:

United States:

National Water Well Association
500 West Wilson Bridge Road
Suite 135
Worthington, OH 43085

U.S. Environmental Protection Agency
401 M Street, SW
Washington, D.C. 20460

U.S. Environmental Protection Agency
Region V, Office of Public Affairs
230 S. Dearborn
Chicago, IL 60604
(Safe drinking water "hotline"
1-800-426-4791)

U.S. Geological Survey
National Center
Reston, VA 22092

Environmental Task Force
1346 Connecticut Ave., Suite 912
Washington D.C. 20036

Environmental Defense Fund
1616 P Street NW
Washington D.C. 20036

American Water Works Association
1010 Vermont Ave. NW
Washington D.C. 20005

The Freshwater Foundation
2500 Shadywood Road, Box 90
Navarre, MN 55392

Wisconsin:

Wisconsin Geological and Natural History Survey
3817 Mineral Point Road
Madison, WI 53705

U.S. Geological Survey
Wisconsin Office
1815 University Avenue
Madison, WI 53706

Department of Natural Resources
Box 7921
Madison, WI 53707

Bureau of Water Resources Management
Bureau of Water Supply
Bureau of Information and Education
Six district offices with groundwater coordinators.

Department of Health and Social Services
Bureau of Community Health and Prevention
Box 309
Madison, WI 53707

Department of Industry, Labor and Human Relations
(regulations for septic and other underground storage tanks)
Safety and Buildings Division
Box 7969
Madison, WI 53707

Department of Agriculture, Trade and Consumer Protection
(pesticide use and regulations)
Agricultural Resource Management Division
Box 8911
Madison, WI 53707

University of Wisconsin-Extension
(agricultural practices, water supply, waste disposal, etc.)

Environmental Resources Unit
216 Agriculture Hall
1450 Linden Drive
Madison, WI 53706

University of Wisconsin-Madison
Water Resources Center
1975 Willow Drive
Madison, WI 53706

Central Wisconsin Groundwater Center
010 Student Services Building
University of Wisconsin—Stevens Point
Stevens Point, WI 54481

State Laboratory of Hygiene
University of Wisconsin
465 Henry Mall
Madison, WI 53706

Citizens for a Better Environment
111 King Street
Madison, WI 53703

League of Women Voters
Wisconsin Chapter
121 S. Hancock Street
Madison, WI 53703-3447

Wisconsin's Environmental Decade
14 W. Mifflin Street
Madison, Wisconsin 53703

WATER RESOURCES CURRICULA:

Discovering Groundwater: A Supplementary Activities Guide for Upper Elementary Social Studies and Science Classes. 1984. WI DNR, Western District. (Out of print)

Aquatic Project WILD. 1987. Western Regional Environmental Education Council. For workshop information, contact Project WILD Wisconsin, WI Department of Natural Resources, Box 7921, Madison, WI 53707.

Groundwater: A Vital Resource, Student Activities. Cedar Creek Learning Center in cooperation with the Tennessee Valley Authority, Knoxville, TN 37902.

Groundwater: Michigan's Hidden Resource, Workbook. 1989. Michigan Department of Natural Resources, Environmental Response Division, P.O. Box 30028, Lansing, MI 48909.

Groundwater Quality Protection in Oakland County: A Sourcebook for Teachers. 1984. The East Michigan Environmental Action Council, 21220 West 14 Mile Road Birmingham, MI 48010.

GREAT: Groundwater Resources and Educational Activities for Teaching. 1989. Iowa Department of Natural Resources, Wallace Building, Des Moines, IA 50319.

Groundwater: Illinois Buried Treasure, Education Activity Guide. 1989. Illinois Department of Natural Resources, Office of Resources and Planning, 325 W. Adams, Room 300, Springfield, IL 62704-1892.

Earth: The Water Planet. J. Gartrell, J. Crowder and J. Callister, National Science Teachers Association. 1742 Connecticut Ave. NW, Washington, DC 20009.

Groundwater Study Guide. 1984. Wisconsin Department of Natural Resources. (out of print)

Local Watershed Problem Studies. 1981. Cooperative Educational Service Agency 16, Waukesha, WI and the Water Resources Center 1975 Willow Drive, Madison, WI. (out of print)

OUTLOOK. A series of groundwater curricula for upper elementary through high-school. For information, contact Institute for Environmental Education, McCollum Science Hall, University of Northern Iowa, Cedar Falls, IA 50614.

Ground-Water Protection Curriculum Guide. Missouri Department of Natural Resources, P.O. Box 176, Jefferson, MO 65102.

Recycling Study Guide. 1988 WI DNR, Bureau of Information and Education, Box 7921, Madison, WI 53707.

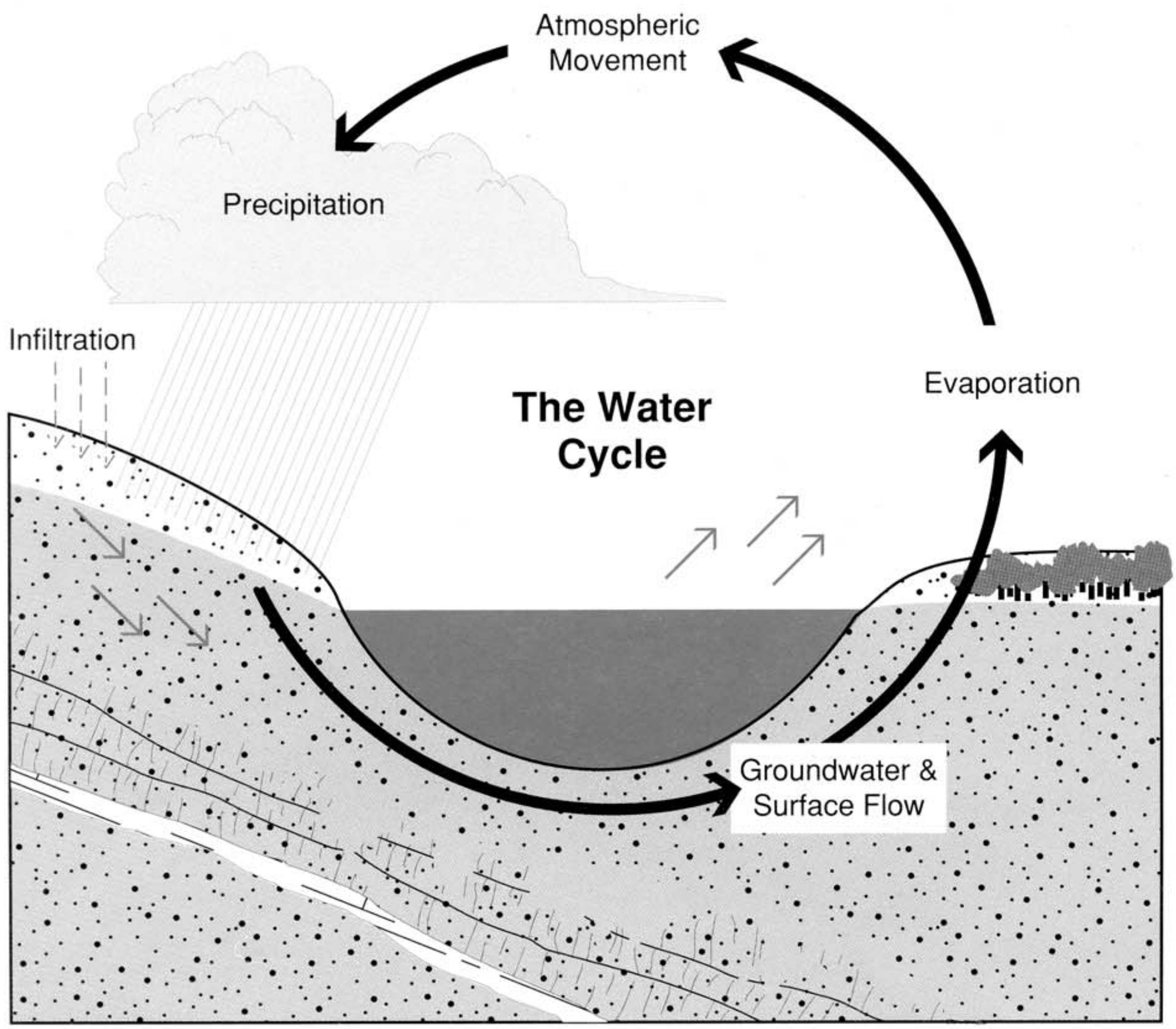
A Sense of Water. Southern Arizona Water Resources Association, 465 W. St. Mary's Road, Suite 100, Tucson, AZ 85705.

Water-Related Teaching Activities. 1977. H. Coon and C. Price. ERIC Center for Science, Mathematics and Environmental Education, Ohio State University, 1200 Chambers Roads, 3rd floor, Columbus, OH 43212.

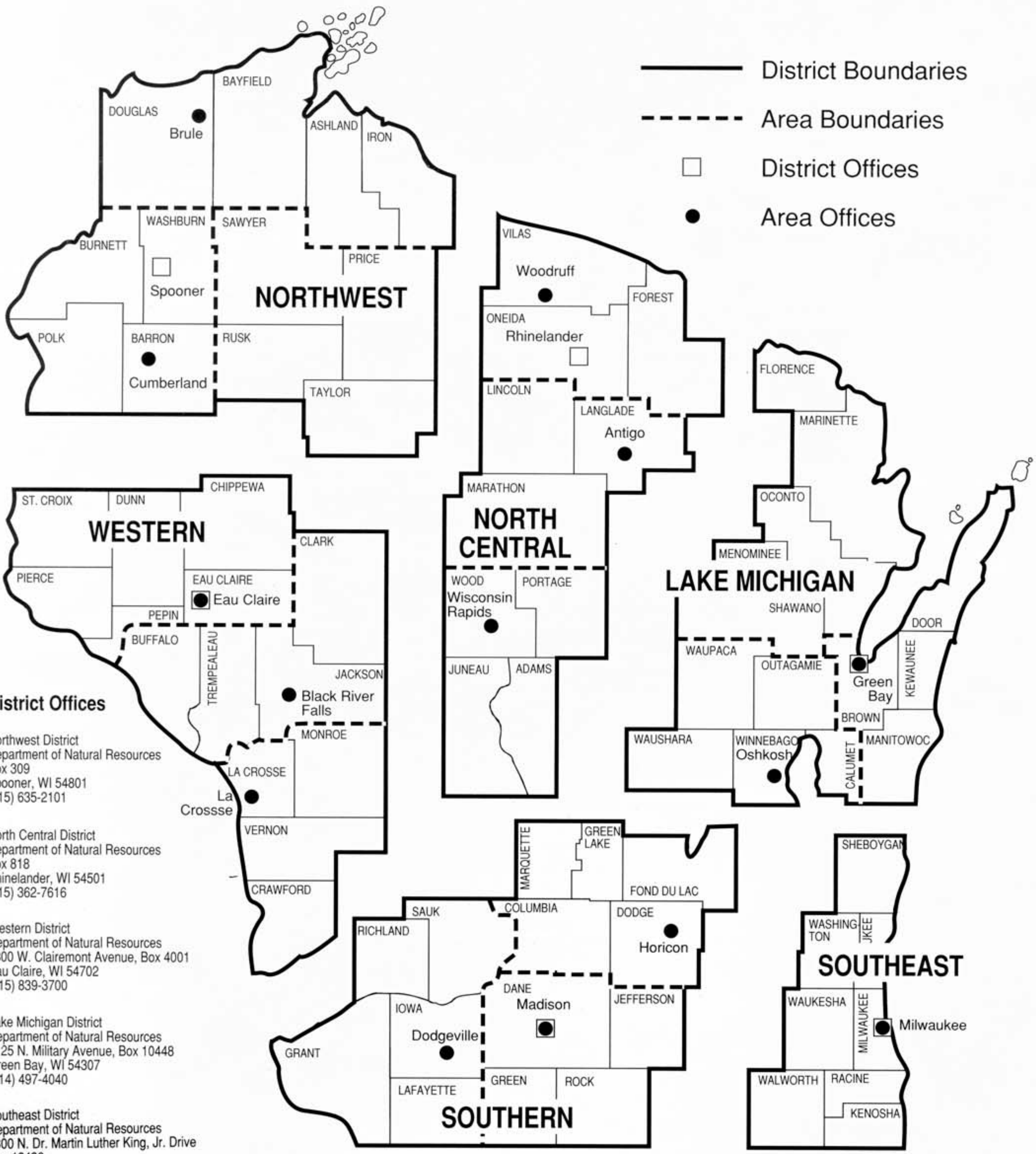
ADDITIONAL EDUCATIONAL MATERIALS:

Groundwater Flow Demonstration Model. Two-dimensional Plexiglass groundwater model. Available on loan basis or for sale. Contact: Central Wisconsin Groundwater Center, 010 Student Services Building, University of Wisconsin-Stevens Point, Stevens Point, WI 54481, (715) 346-4270

Household Hazardous Waste Wheel and Water Sense Wheel (home water conservation ideas) may be purchased from: EMHI, 10 Newmarket Road, P.O. Box 932, Durham, NH 03824



DNR Field Districts and Areas



District Offices

- Northwest District
  Department of Natural Resources
  Box 309
  Spooner, WI 54801
  (715) 635-2101

- North Central District
  Department of Natural Resources
  Box 818
  Rhinelander, WI 54501
  (715) 362-7616

- Western District
  Department of Natural Resources
  1300 W. Clairemont Avenue, Box 4001
  Eau Claire, WI 54702
  (715) 839-3700

- Lake Michigan District
  Department of Natural Resources
  1125 N. Military Avenue, Box 10448
  Green Bay, WI 54307
  (414) 497-4040

- Southeast District
  Department of Natural Resources
  2300 N. Dr. Martin Luther King, Jr. Drive
  Box 12436
  Milwaukee, WI 53212
  (414) 263-8500

- Southern District
  Department of Natural Resources
  3911 Fish Hatchery Road
  Fitchburg, WI 53711
  (608) 275-3266

Rev. 2/1990

The purpose of the Department of Natural Resources study guides is to help increase Wisconsin citizens' knowledge about and understanding of our state's environment. We hope to provide information about important environmental issues, encourage respect for the environment and help citizens become active stewards of our natural resources.

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Author and project coordinator: Jo Temte

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Please address comments and questions about this study guide to:

Bureau of Information and Education
Education Section
Wisconsin Department of Natural Resources
Box 7921
Madison, Wisconsin 53707

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'Round and 'Round it Goes activity sheet

Part A

Look carefully at the "Water Cycle" poster. Using information from the poster (and what you already know about water), complete the following questions:

1. Where do you see water on the poster?

____

____

____

2. Where else is water found on Earth?

____

____

____

3. The process by which water moves from the surface of plants to the atmosphere is called ____________________.

The process by which water moves from the surface of soil, water, buildings, and parking lots, to the atmosphere is called ____________________.

4. Water forms clouds in the atmosphere and falls to earth as ______________________________,

______________________________, ______________________________, or sleet.

5. Where does water go after it falls as precipitation?

____

____

____

6. What effect does the sun have on the water cycle? What effect does gravity have?

____

____

____

____

7. How is groundwater used by people? How do we get water out of the ground?

8. How many wells are shown on the poster? How is water from these wells used?

9. List the human activities (shown on the poster) that could affect groundwater quality. Can you think of others?

10. If a truck carrying chemicals overturned and a chemical pollutant was spilled near the abandoned mine shaft at the far right side of the poster, where might it end up? (There are lots of possibilities!)

Part B

Using the poster, what you already know about water, and a dictionary, define the following terms.

hydrologic or water cycle

____

____

____

water table

____

____

____

aquifer

____

____

____

precipitation

____

____

____

runoff

____

____

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condensation

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____

evaporation

____

____

____

groundwater

____

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____

infiltration

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____

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transpiration

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Wisconsin's Water Cycle	
Average precipitation:	32.0 inches/year
Average runoff:	3.0 inches/year
Evaporation and transpiration:	22.0 inches/year
Becomes groundwater	7.0 inches/year
(Values vary with location.)	

Part C

1. What fraction of the annual average precipitation returns to the atmosphere as a result of evaporation and transpiration? ____________________

2. Is any water lost from the cycle? _________________

3. Does all the water that soaks into the ground remain underground?_______ If not, where does it go?

____

____

____

4. About what percentage of the total annual precipitation becomes groundwater? _____________

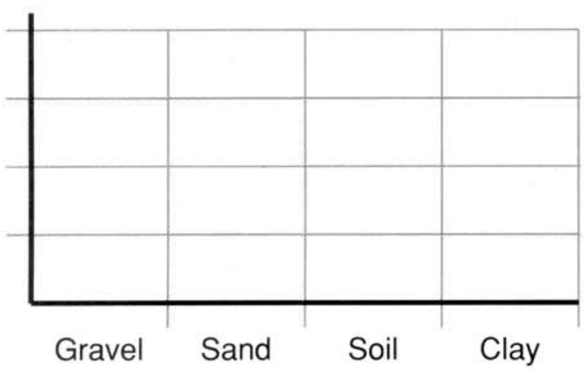
Porosity and Permeability activity sheet

A. Complete the following table:

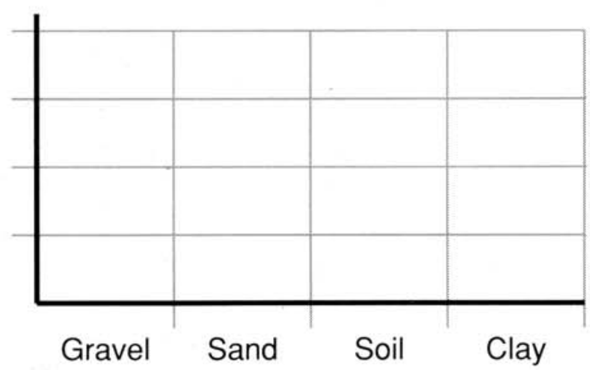
Material	Total Volume (mililiters)	Pore Space (mililiters)	Porosity (% Pore Space)	Permeability
Gravel				
Sand				
Soil				
Clay				
Porosity = (Pore Space ÷ Total Volume) x 100				

B. **Make bar graphs of your results.** Label the axes on your graphs (don't forget to add the units).

Porosity



Permeability



* Remember, the material through which water takes the longest time to flow is the LEAST permeable.

C. Answer the following questions:

1. Which material is **most** porous? ______________________________

2. Which material is **least** porous? ______________________________

3. Rate the materials in terms of their permeability.

1 ______________________________(Least permeable)

2 ______________________________

3 ______________________________

4 ______________________________(Most permeable)

4. How does soil type affect the movement of groundwater?

____

____

____

____

____

____

5. Do you think soil can help protect groundwater from pollution? If so, how?

____

____

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____

____

Well, Well, Well
activity sheet

1. How do wells bring groundwater to the surface?

____

____

____

2. What happens to the water table as water is pumped from the ground?

____

____

3. What must happen for the water table to remain at the same level when water is being pumped out?

____

____

4. How do pollutants move from surface water into groundwater? (Note: Groundwater can be recharged—and polluted—by surface water, especially if large volumes of water are being pumped from the ground, but surface water usually represents a "discharge area" where groundwater comes to the surface and evaporates into the atmosphere.)

____

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____

____

5. How can pollutants be detected in well water? Can all pollutants be detected?

____

____

____

____

____

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Wisconsin's Major Aquifers activity sheet (Northern Wisconsin)

1. On the diagram of Wisconsin's major aquifers, label the layers of rock on the cross-section:

    a) Sand and gravel aquifer
    b) Eastern dolomite aquifer
    c) Maquoketa shale confining layer
    d) Sandstone and dolomite aquifer
    e) Crystalline bedrock aquifer

2. Use colored pencils to color the AQUIFERS different colors.

3. Answer the following questions:

a) Describe the arrangement and shape of the layers shown on the diagram.

____

____

____

____

____

____

b) What are confining layers?

____

____

c) How do they affect groundwater movement?

____

____

d) Name the aquifer used by each of the following cities:

Hudson ____________________

Eau Claire ____________________

Junction City ____________________

Stevens Point ____________________

De Pere ____________________

e) Using the scale on the left margin of the diagram, estimate the depths of wells at these cities.

Hudson ______________________________ ft. Stevens Point ____________________________ ft.

Eau Claire ____________________________ ft. De Pere _________________________________ ft.

Junction City _________________________ ft.

f) According to the diagram, which city's well would you expect to be the most susceptible to contamination?

____

Why?

____

____

____

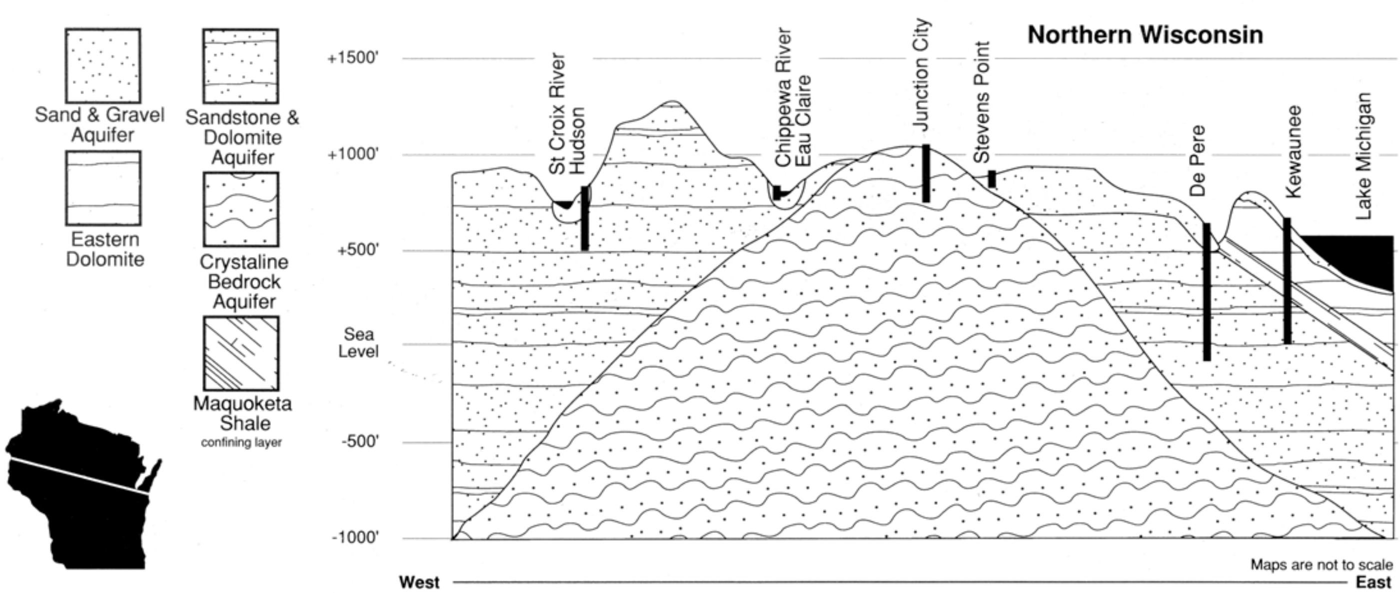
g) Water that has been in bedrock a long time often contains many dissolved minerals. This water may have to be treated to improve its taste, odor or color. According to the diagram, which city's well do you think is most likely to have a problem with dissolved minerals?

____

Why?

____

____



Wisconsin's Major Aquifers activity sheet (Southern Wisconsin)

1. On the diagram of Wisconsin's major aquifers, label the layers of rock on the cross-section:

    a) Sand and gravel aquifer
    b) Eastern dolomite aquifer
    c) Maquoketa shale confining layer
    d) Sandstone and dolomite aquifer
    e) Crystalline bedrock aquifer

2. Use colored pencils to color the AQUIFERS different colors.

3. Answer the following questions:

a) Describe the arrangement and shape of the layers shown on the diagram.

____

____

____

____

____

____

b) What are confining layers?

____

____

c) How do they affect groundwater movement?

____

____

d) Name the aquifer used by each of the following cities:

Prairie du Chien ______________________

Boscobel ______________________

Madison ______________________

Waukesha ______________________

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e) Using the scale on the left margin, estimate the depths of wells at these cities.

Prairie du Chien ______________________ft. Madison ________________________________ ft.

Boscobel _____________________________ft. Waukesha _______________________________ ft.

f) According to the diagram, which city's well would you expect to be the most susceptible to contamination?

____

Why?

____

____

____

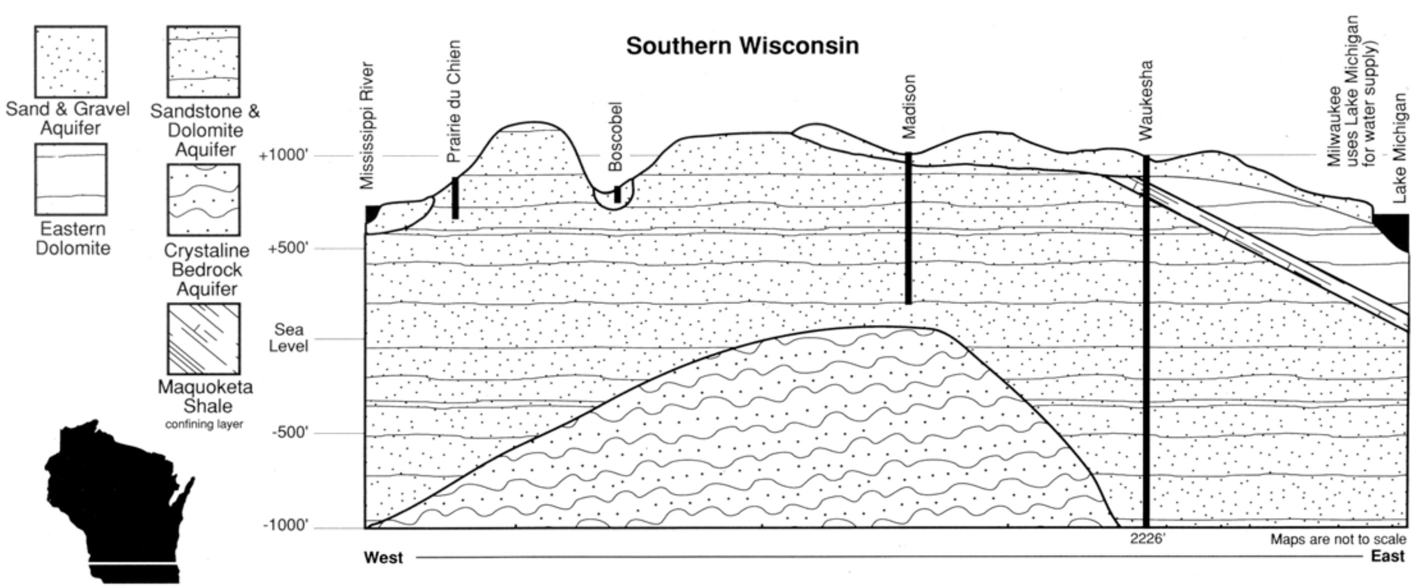
g) Water that has been in bedrock a long time often has many dissolved minerals in it. This water may have to be treated to improve its taste, odor or color. According to the diagram, which city's well do you think is most likely to have a problem with dissolved minerals?

____

Why?

____

____



A Plume of Contamination activity sheet

Instructions:

1. Using pH paper, determine the pH of tap water.

pH of tap water ___________

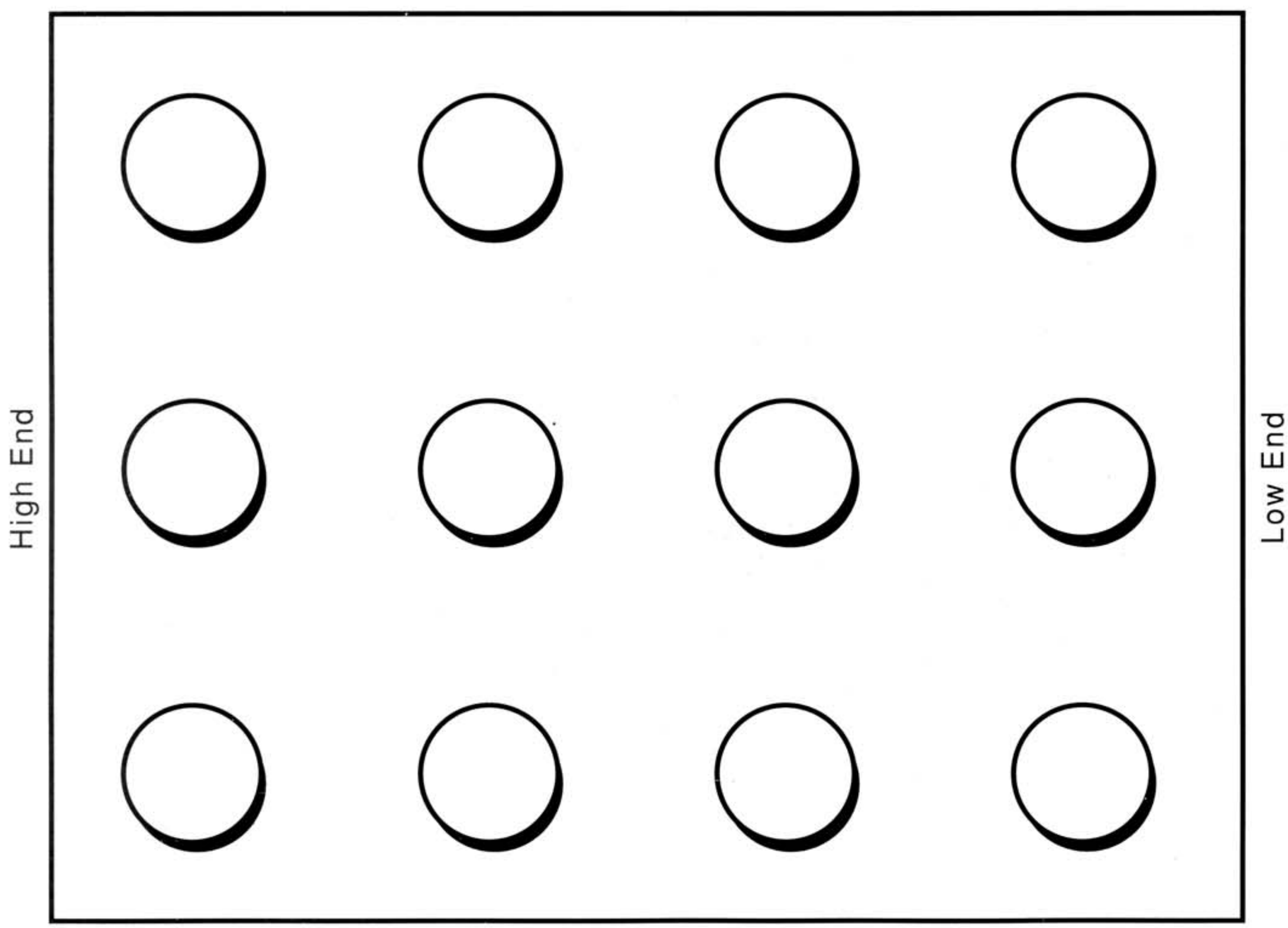
2. Take a sample of sand and "groundwater" from each test well location indicated. Test the groundwater at each location for contamination by placing the sand sample on a strip of pH paper. Rinse the straw after each sample.

3. Record your results for each location on the table below:

+ = contamination found (pH of sample < water)

- = no contamination (pH of sample = water)

Record the results directly on each test well location.



4. Based on the results of your tests, sketch the shape of the plume of contamination.

5. Are there enough "test wells" to determine the source of contamination? ______________________________

6. If you were to select three additional "test well" locations, where would they be? Indicate your proposed locations with the letter "T" on the activity sheet.

7. Rinse the straws with tap water and test the groundwater at each new test well location. Record your results. If the results show contamination, mark the well with a T+. If the results show no contamination, label the well T-.

8. Are more test wells needed to show the extent of the plume of contamination? ______________________________

How Septic Systems Work
activity sheet

Part A: Simulation

1. Prepare a "wastewater" sample—water, sand, small bits of paper and 2-3 drops of green food coloring.

2. Construct a model septic tank system:

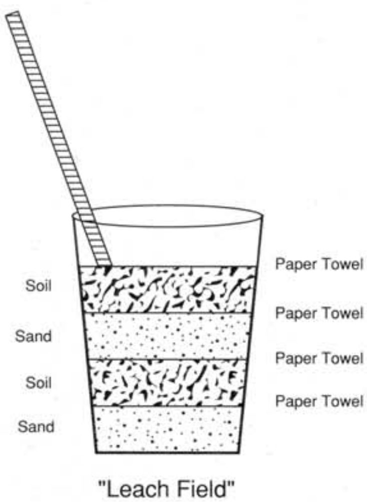
    a) Label small beaker or jar "septic tank."

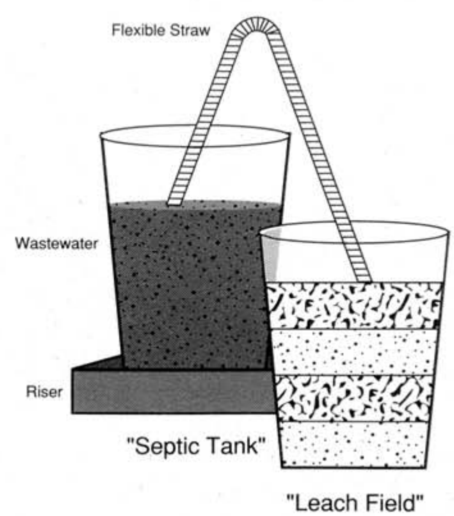
    b) Pour a well-stirred sample of wastewater into the septic tank until it is about 3/4 full.

    c) Allow sample to settle and observe. Record your observations.

    d) Prepare a "leach field" as follows: To large beaker or jar add alternating layers of sand and potting soil, separated by paper towels (as shown). Wet the "leach field" with water.

    e) Set the septic tank on a book or other riser. Place the leach field directly below the septic tank. Bend the flexible straw and fill it with water. Place fingers over both ends to keep the water in. After the wastewater has settled, connect the septic tank with the leach field as shown. Keep fingers over the ends of the straw until it is placed in the wastewater. This should create a siphon, allowing the wastewater to flow onto the leach field. (If wastewater doesn't flow through the siphon, try again!) Observe the action of wastewater on the leach field.





Part B: Survey

Interview a friend or relative who has a septic tank system (instead of being connected to a municipal wastewater treatment plant). Find answers to the following questions:

1. Where does their water come from?

____

____

2. If their water is from a private well, how far is their septic tank from the well?

____

3. How far is the leach field from their well?

____

4. How far is their house from the septic tank?

____

5. How far is their house from the leach field?

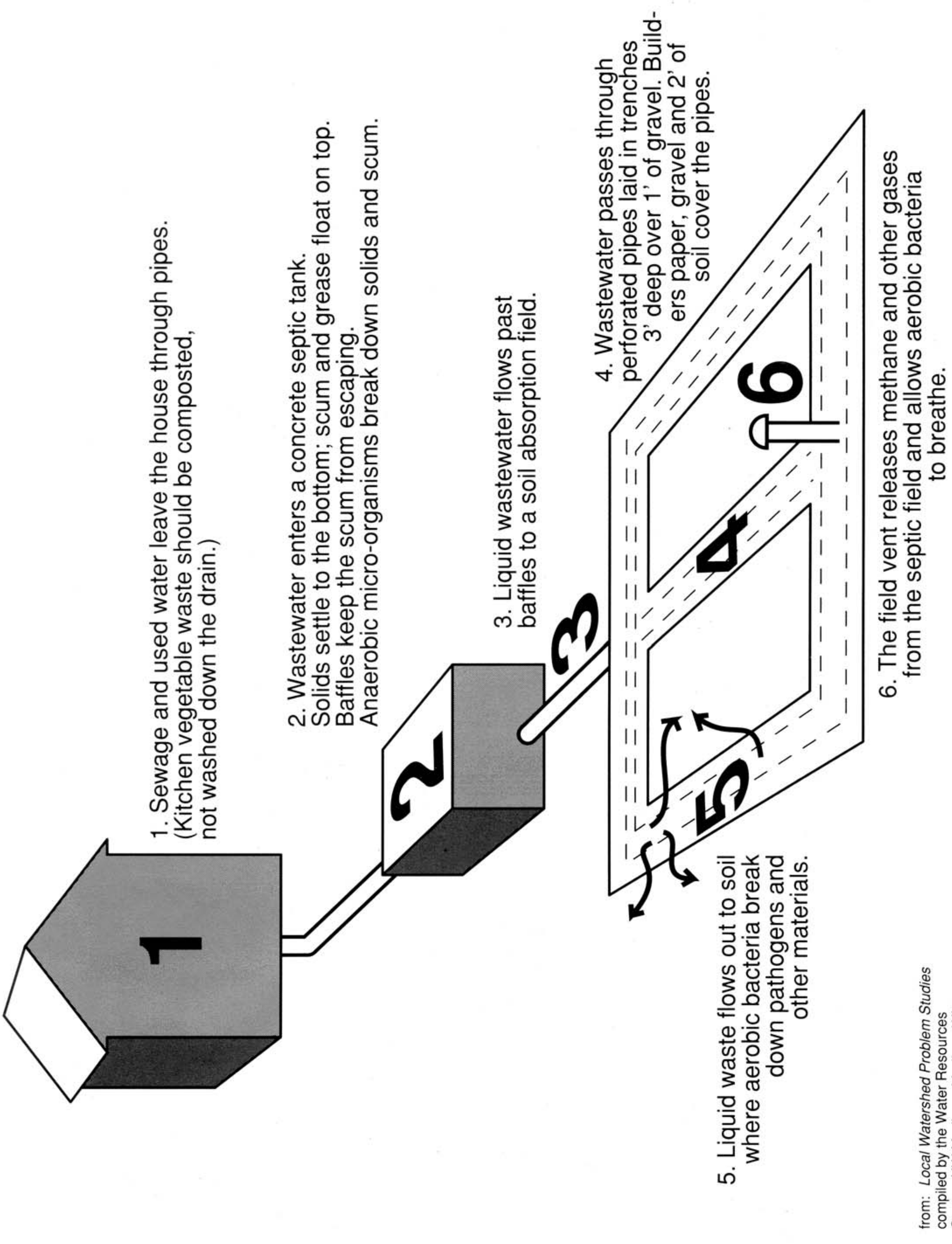
____

6. Refer to the table below. Is there anything closer to the septic tank or leach field than the recommended minimum separation distance? If so, circle the unit and record next to the table how close it is.

7. What is one other factor (besides separation distance) to consider when planning a septic system?

____

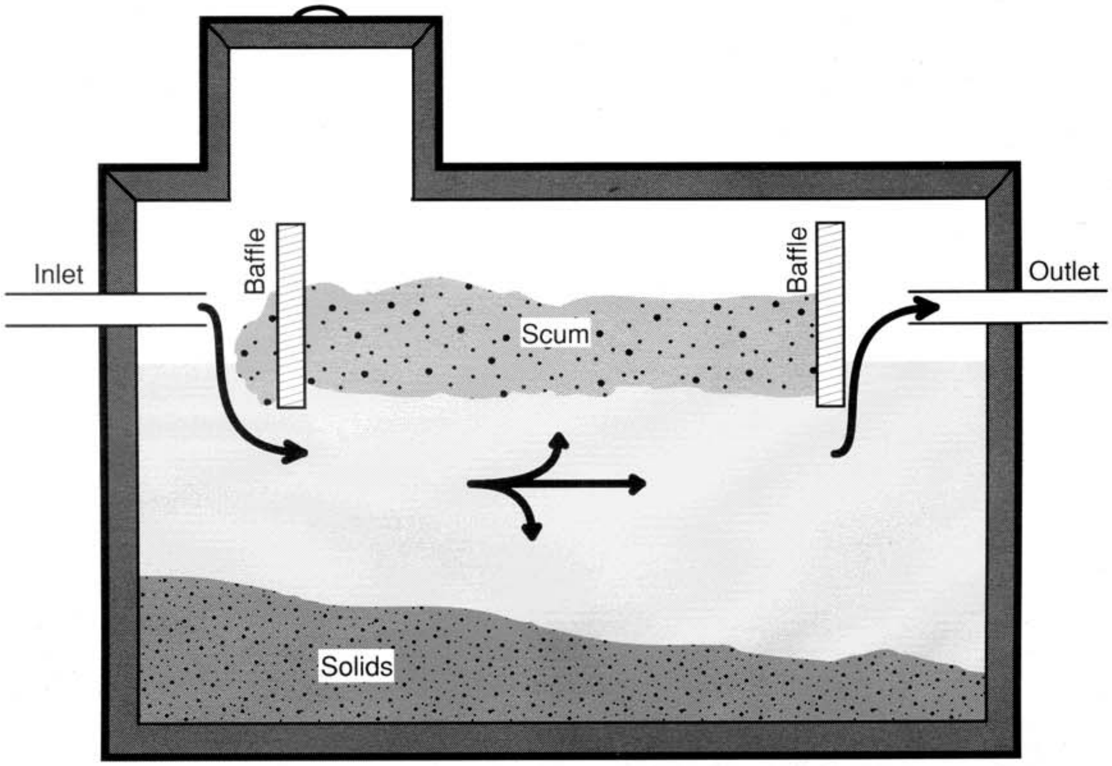
Unit	Septic Tank	Absorption Field
Private well	50	100
Public well	200	400
Lake or reservoir	50	100
Stream or ditch	25	25
House or other building	10	10



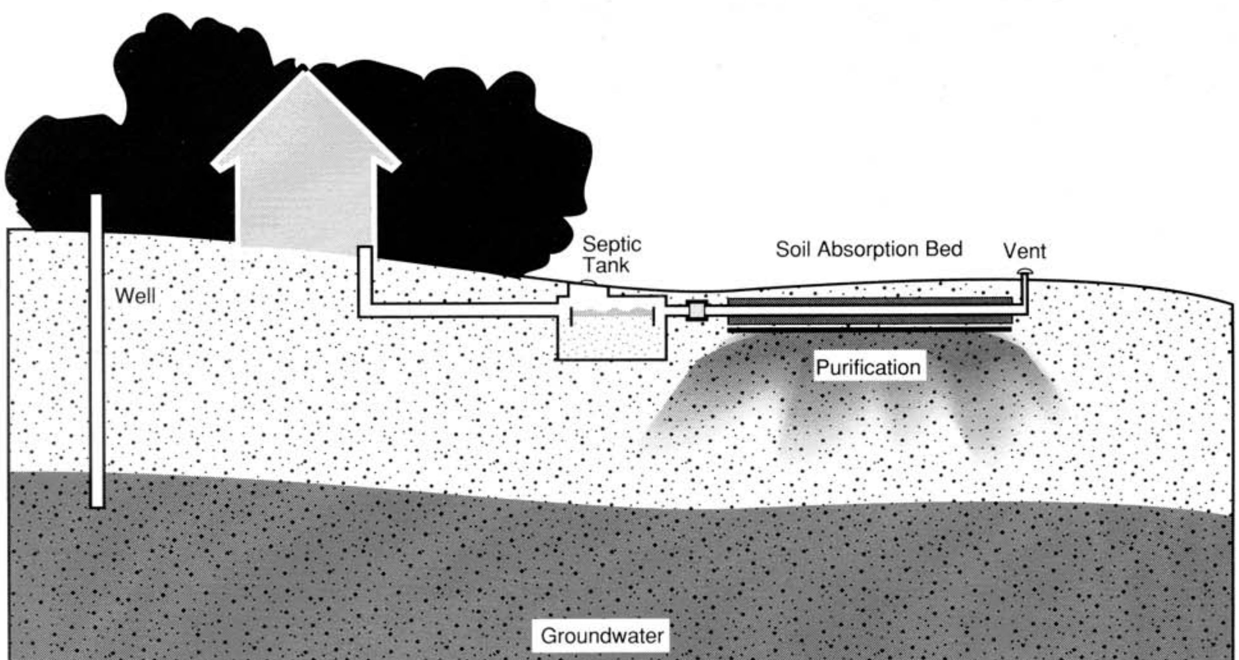
from: *Local Watershed Problem Studies* compiled by the Water Resources Center, UW Madison, Madison WI

Overhead Master

The Septic Tank at Work

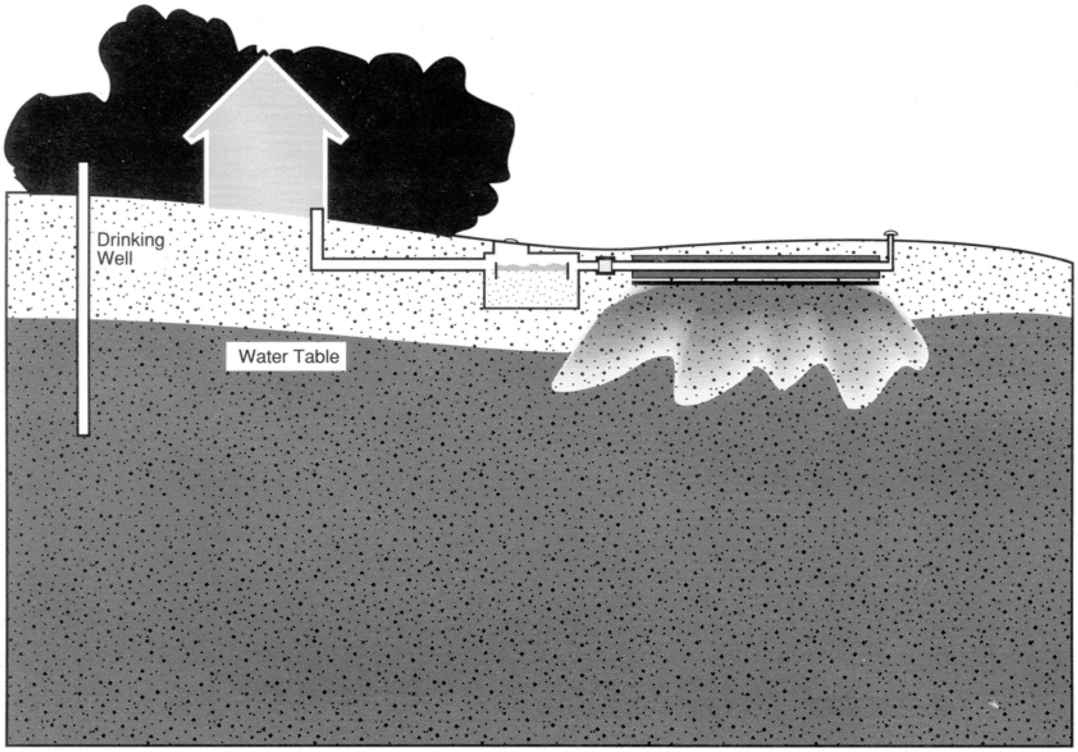


Filtering bacteria



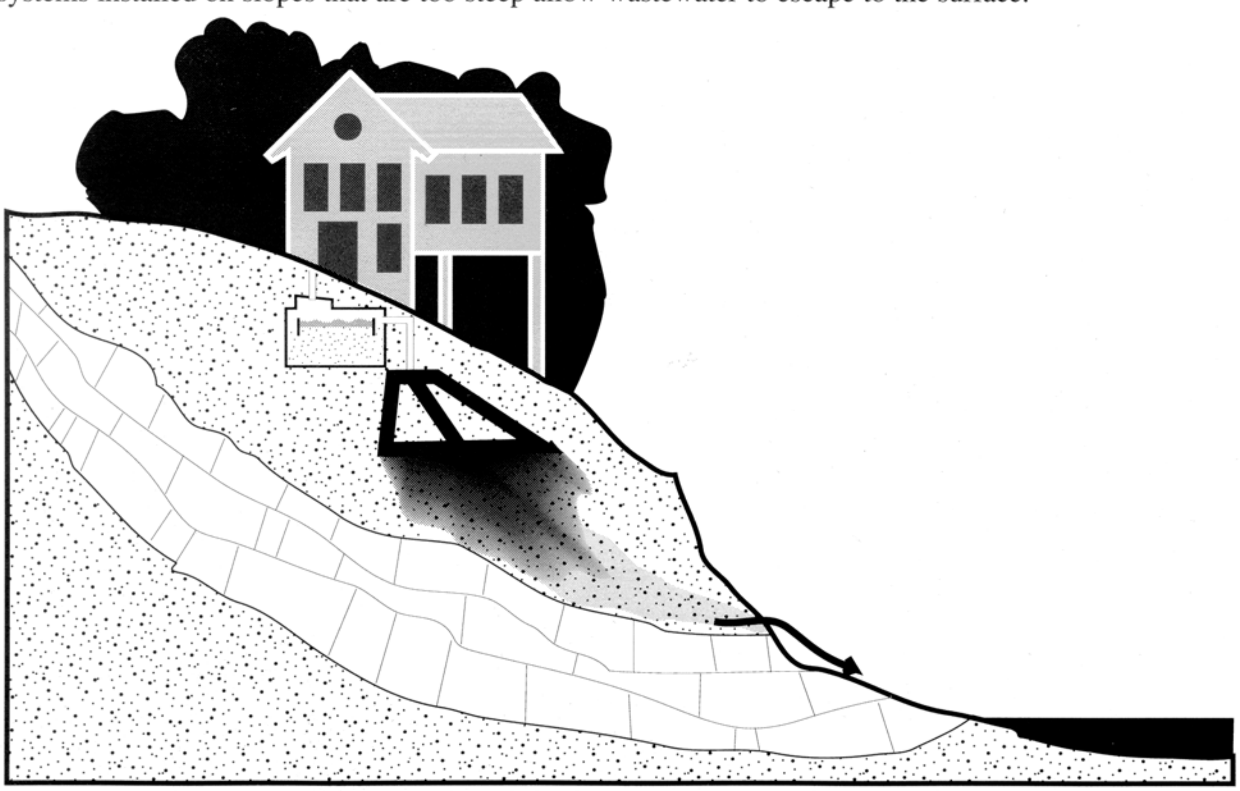
Saturated soil

Saturated soil conditions may allow wastewater to reach the surface or to contaminate groundwater.



Septic system on a slope

Septic systems installed on slopes that are too steep allow wastewater to escape to the surface.



Reading Product Labels
activity sheet

ACTIVE INGREDIENTS:

Trisodium Phosphate	13.50 %
Sodium Sesqui Carbonate	1.90 %
Potassium hypochlorite	0.45%

INERT INGREDIENTS:* 85.15 %

* Includes Sodium tripolyphosphate, color, perfume, quality control agents. Whiz Clean averages 31% phosphorus, in the form of phosphates.

Bleaches out food and stains

Cleans and disinfects

USE WHIZ CLEAN ANYWHERE IN YOUR HOME

Kitchens

Sinks: Whiz Clean cleans and whitens porcelain, cleans stainless steel to a sparkle.

Countertops, plastic surfaces: Whiz Clean bleaches out food, beverage, ink stains. Wet, sprinkle Whiz Clean, let soak, then rub only as needed. Rinse. Do not soak for long periods.

Pots and pans, stoves, ceramic cookware: Whiz Clean cuts grease, scours off cooked-on food.

Bathrooms

Sinks, tubs and showers: Whiz Clean disinfects as it cleans.

Ceramic tile, fixtures: Whiz Clean cleans to a sparkle.

Toilet bowls: Whiz Clean cleans and sanitizes. Sprinkle Whiz Clean liberally into bowl, scour and flush.

WARNING: Harmful to eyes and skin. If Whiz Clean contacts eyes, flush with water and contact physician. Harmful or fatal if swallowed.

1. What is the brand name of this product? ______________________________

2. What is the product used for?

____

____

3. What is the total weight of the product? ______________________________

4. List three active ingredients and calculate the weight for each:

	Chemical Name	% Total Weight	Weight of the Ingredient
1			
2			
3			

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5. How should the product be used? Circle all directions on the label.

6. Are there any directions, warnings, or precautions for protecting health and/or the environment? ______________

If so, then list them:

____

____

____

____

____

____

7. Does the label tell you how much to apply each time the product is used? ______________________

8. Approximately how many applications would it take to use the entire container? ______________________

9. Underline all instructions on the label for storing the product.

10. List instructions for disposing of the product or container:

____

____

____

____

____

____

Dear Parents:

As part of our study of groundwater quality, we are discussing management of household hazardous materials. Nearly everyone uses some type of hazardous material or product in the home. It is important that students be aware of potential health and environmental hazards associated with these products.

The unit on household hazardous materials has two themes:

1. Identification and recognition of household hazardous materials.

2. Managing these products—to protect family health in the home and to protect groundwater quality.

If quantities of household hazardous materials are poured down the drain or onto the backyard, the materials may reach groundwater or flow into nearby lakes and streams. Some can damage your home's plumbing and many can kill essential bacteria at wastewater treatment plants.

We need your help in completing a home activity. The instructions are printed on the activity sheet and can be easily followed by the student. We ask your help in working with the student for safety purposes.

Make sure that all containers of hazardous products are securely closed before beginning activity sheets. While activity sheets are being completed, stay with your child. When the sheets have been completed return the hazardous materials to a safe, child-proof location.

Thank you for your help and cooperation.

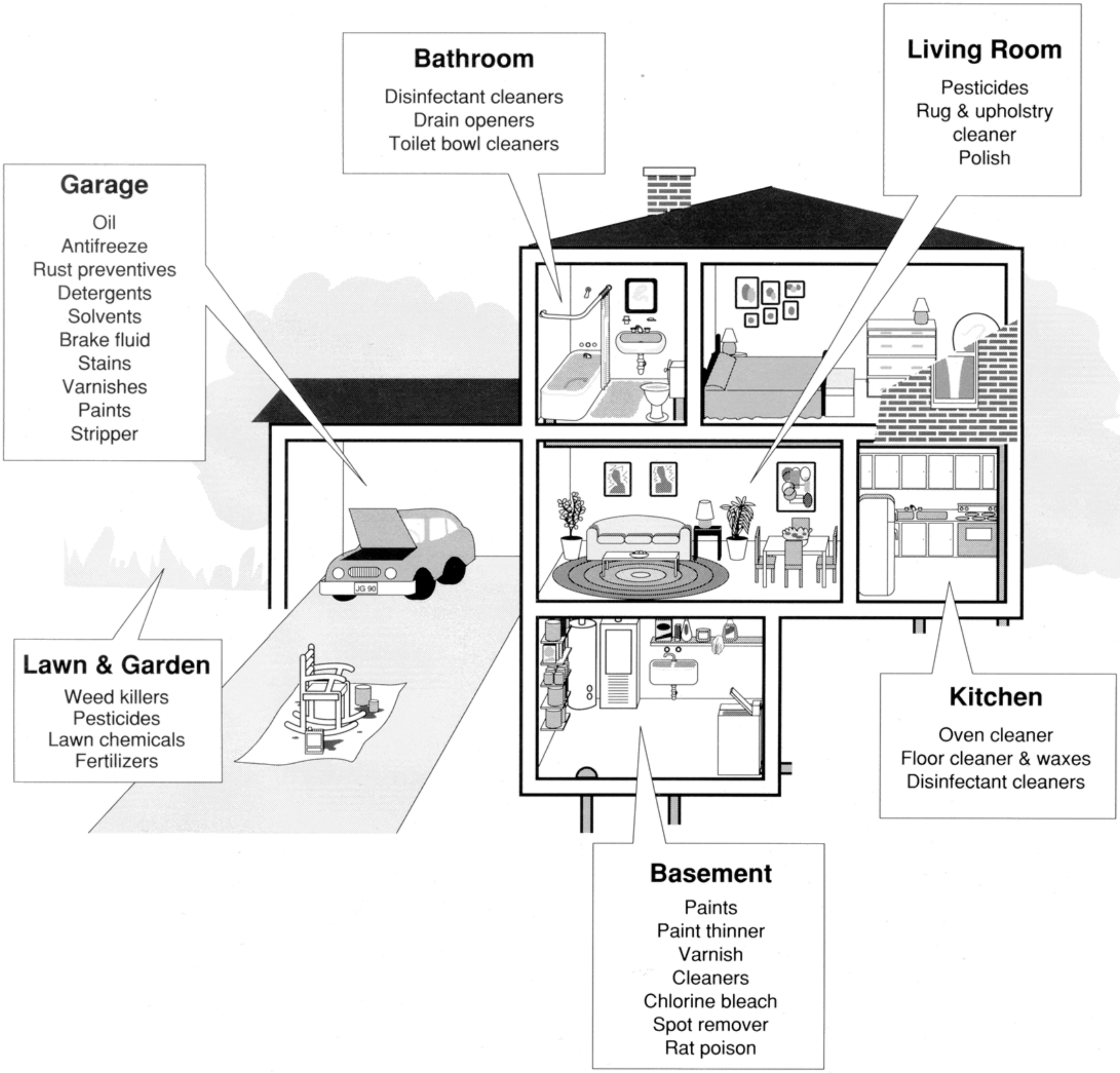
A Home Chemical Search activity sheet

Please read carefully. Before beginning this activity sheet, deliver the home chemical search letter to your parents. When you are completing this activity sheet, try to be as specific as possible in estimating the quantities of products but **Do not touch any of the substances.** Also, wash your hands when you are through to remove any chemical residues that may remain.

*** Substance** (check if found)	*** Estimated amount**	**Toxicity (1 to 6)**	**Proper disposal**	**Alternatives to use**
☐ used motor oil				
☐ old antifreeze				
☐ drain cleaners				
☐ abrasive cleaners				
☐ household disinfectants				
☐ old paint				
☐ stains or preservatives				
☐ solvents, paint thinners turpentine paint strippers, finish removers				
☐ rat poison				
☐ insecticides (kill insects)				
☐ herbicides (kill weeds)				
☐ slug bait				
☐ other garden pesticides				
☐ pet flea collars				
☐ flea sprays				
☐ detergent				
☐ dry cleaning fluids, spot removers				
☐ bleach				
☐ other ________				
☐ ____________				
☐ ____________				
☐ ____________				
☐ ____________				

* Complete these columns only during home chemical search

Location of Household Hazardous Materials



Hazardous materials are chemical substances which can harm, contaminate or kill living organisms.

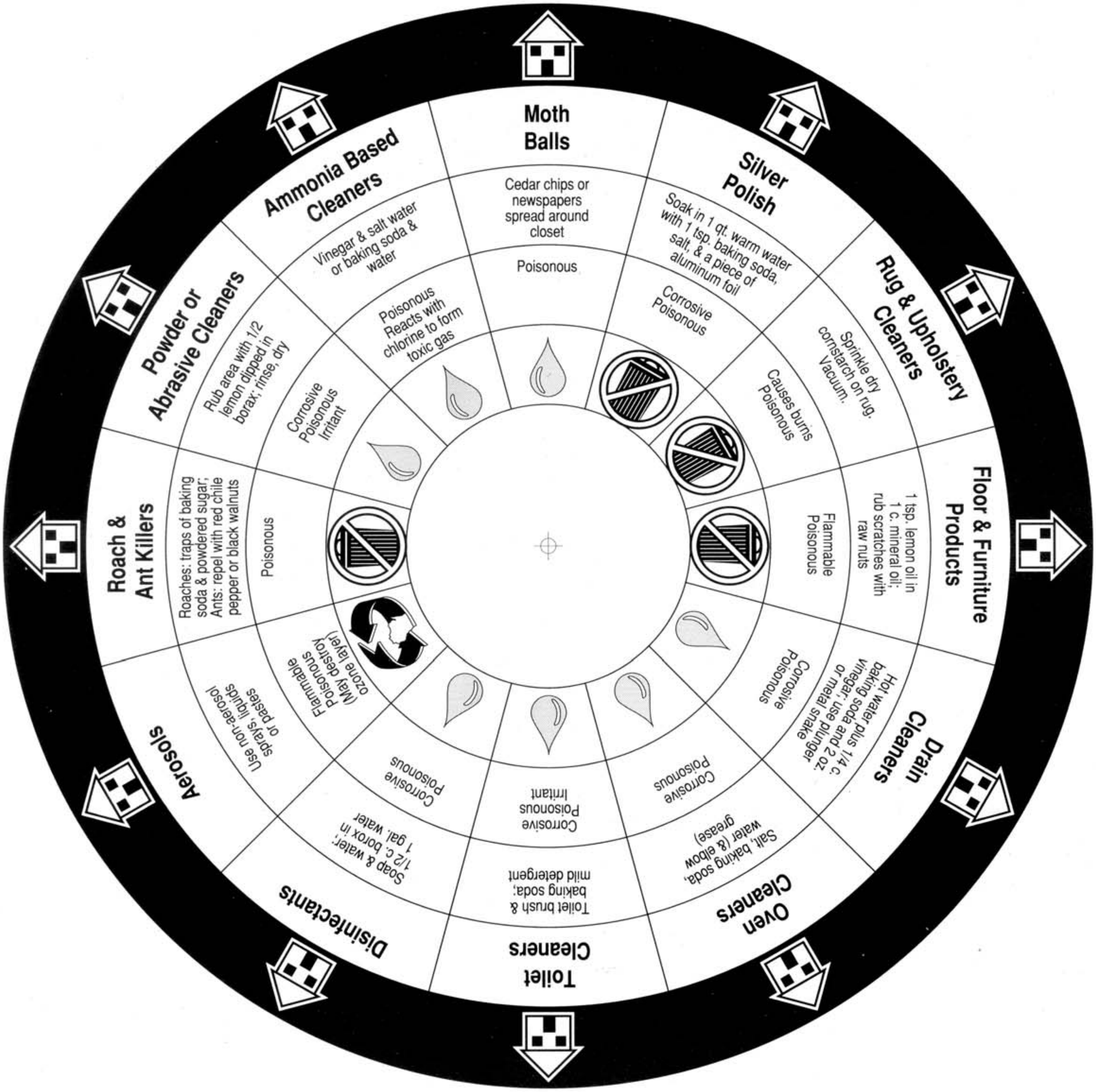
Hazardous materials are dangerous if they are not carefully handled and managed.

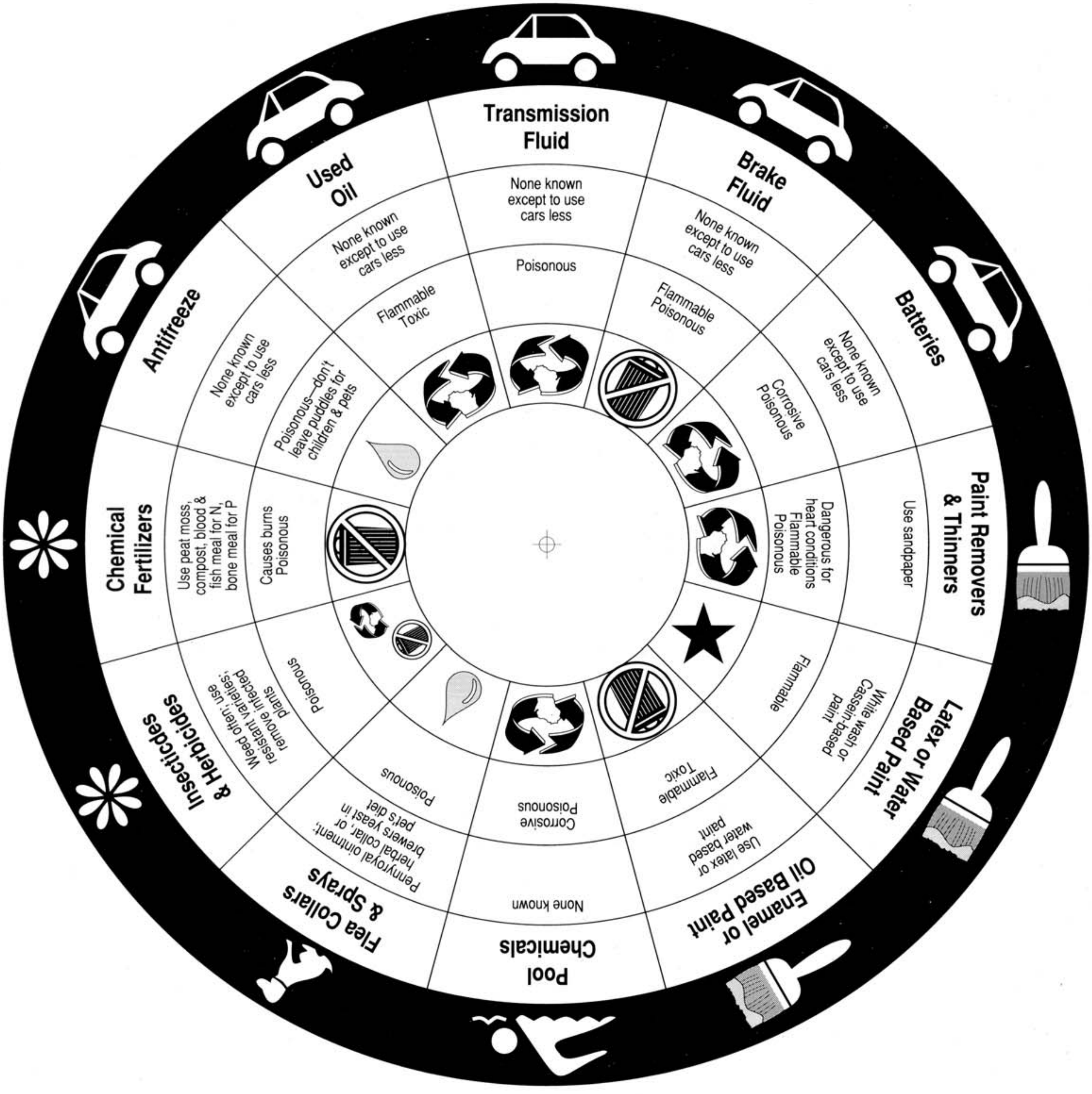
- If used or stored improperly in the home, chemicals can cause skin irritations, sickness and death.
- If disposed of improperly (e.g. poured down the sink or on the backyard) some chemicals can contaminate groundwater.
- With careful management, potential problems can be avoided.

Can Some of Your Household Products Harm You? activity sheet

Toxicity Rating	Lethal Dose (for 150 lb. human)	Household Products
1—Almost Non-Toxic	more than 1 quart	Foods, candies, 'lead' pencils, eye makeup
2—Slightly Toxic	1 pint to 1 quart	dry cell batteries, glass cleaner, deodorants and antiperspirants, hand soap
3—Moderately Toxic	1 ounce to 1 pint	antifreeze, automotive cleaners, household bleaches, many detergents, dry cleaners, most floor cleaners, metal cleaners, most oven cleaners, many general cleaners, most fuels, lubricating oils, most stain and spot removers, many disinfectants, floor polish, shoe polish, most paints
4—Very Toxic	1 teaspoon	most toilet bowl cleaners, some deodorizers, engine motor cleaners, some fertilizers, some paint brush cleaners, some pain and varnish removers, fireworks, some mildew proofing, air sanitizers, some paints lacquer thinners, many pesticides: DDT, chlordane, heptachlor, lindane, mirex diazinon, malathion, diquatdibromide, endothall, 2,4D
5—Extremely Toxic	7 drops to 1 teaspoon	some insecticides, fungicides, rodenticides, herbicides: aldrin, eldrin, bidrin, methylparathion, paraquat, some fertilizers, mercury cell batteries
6—Super Toxic	a taste (less than 7 drops)	a few pesticides like: paroxon, phosdrin, parathion, isobenzan

Gosselin et. al. (1976) *Clinical Toxicology of Commercial Products*


Moth Balls
Cedar chips or newspapers spread around closet
Poisonous
Silver Polish
Soak in 1 qt. warm water with 1 tsp. baking soda, salt, & a piece of aluminum foil
Corrosive Poisonous
Rug & Upholstery Cleaners
Sprinkle dry cornstarch on rug. Vacuum.
Causes burns Poisonous
Floor & Furniture Products
1 tsp. lemon oil in 1 c. mineral oil; rub scratches with raw nuts
Flammable Poisonous
Drain Cleaners
Hot water plus 1/4 c. baking soda and 2 oz. vinegar; use plunger or metal snake
Corrosive Poisonous
Oven Cleaners
Salt, baking soda, water (& elbow grease)
Corrosive Poisonous
Toilet Cleaners
Toilet brush & baking soda; mild detergent
Corrosive Poisonous Irritant
Disinfectants
Soap & water; 1/2 c. borox in 1 gal. water
Corrosive Poisonous
Aerosols
Use non-aerosol sprays, liquids or pastes
Flammable Poisonous (May destroy ozone layer)
Roach & Ant Killers
Roaches: traps of baking soda & powdered sugar; Ants: repel with red chile pepper or black walnuts
Poisonous
Powder or Abrasive Cleaners
Rub area with 1/2 lemon dipped in borax; rinse, dry
Corrosive Poisonous Irritant
Ammonia Based Cleaners
Vinegar & salt water or baking soda & water
Poisonous Reacts with chlorine to form toxic gas


Transmission Fluid
None known except to use cars less
Poisonous
Brake Fluid
None known except to use cars less
Flammable Poisonous
Batteries
None known except to use cars less
Corrosive Poisonous
Paint Removers & Thinners
Use sandpaper
Dangerous for heart conditions Flammable Poisonous
Latex or Water Based Paint
White wash or Cassein-based paint
Flammable
Enamel or Oil Based Paint
Use latex or water based paint
Flammable Toxic
Pool Chemicals
None known
Corrosive Poisonous
Flea Collars & Sprays
Pennyroyal ointment; herbal collar, or brewers yeast in pet's diet
Poisonous
Insecticides & Herbicides
Weed often; use resistant varieties; remove infected plants
Poisonous
Chemical Fertilizers
Use peat moss, compost, blood & fish meal for N, bone meal for P
Causes burns Poisonous
Antifreeze
None known except to use cars less
Poisonous—don't leave puddles for children & pets
Used Oil
None known except to use cars less
Flammable Toxic

WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

GROUNDWATER
Wisconsin's
buried treasure

Household Hazardous Waste Wheel

Cut out this window

Waste Category

Products

Alternatives

Immediate Hazards

Waste Disposal

Disposal Key:

Hazardous waste program
Do not dispose. Keep safely stored until a hazardous waste collection is held nearby.

Dispose with water
After product has been used, rinse container. Pour rinse water down drain that empties into a sanitary sewer with lots of water or reuse container according to label directions. Usually rinsed containers may be deposited in landfill.

Recycle
Bring to a reclamation center or find someone who can use it.

Special Disposal
Air dry latex paints in a cardboard box. Evaporate and solidify. Discard empty containers and cardboard boxes after drying.

WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

GROUNDWATER
Wisconsin's buried treasure

Household Hazardous Waste Wheel

Cut out this window

Waste Category

Products

Alternatives

Immediate Hazards

Waste Disposal

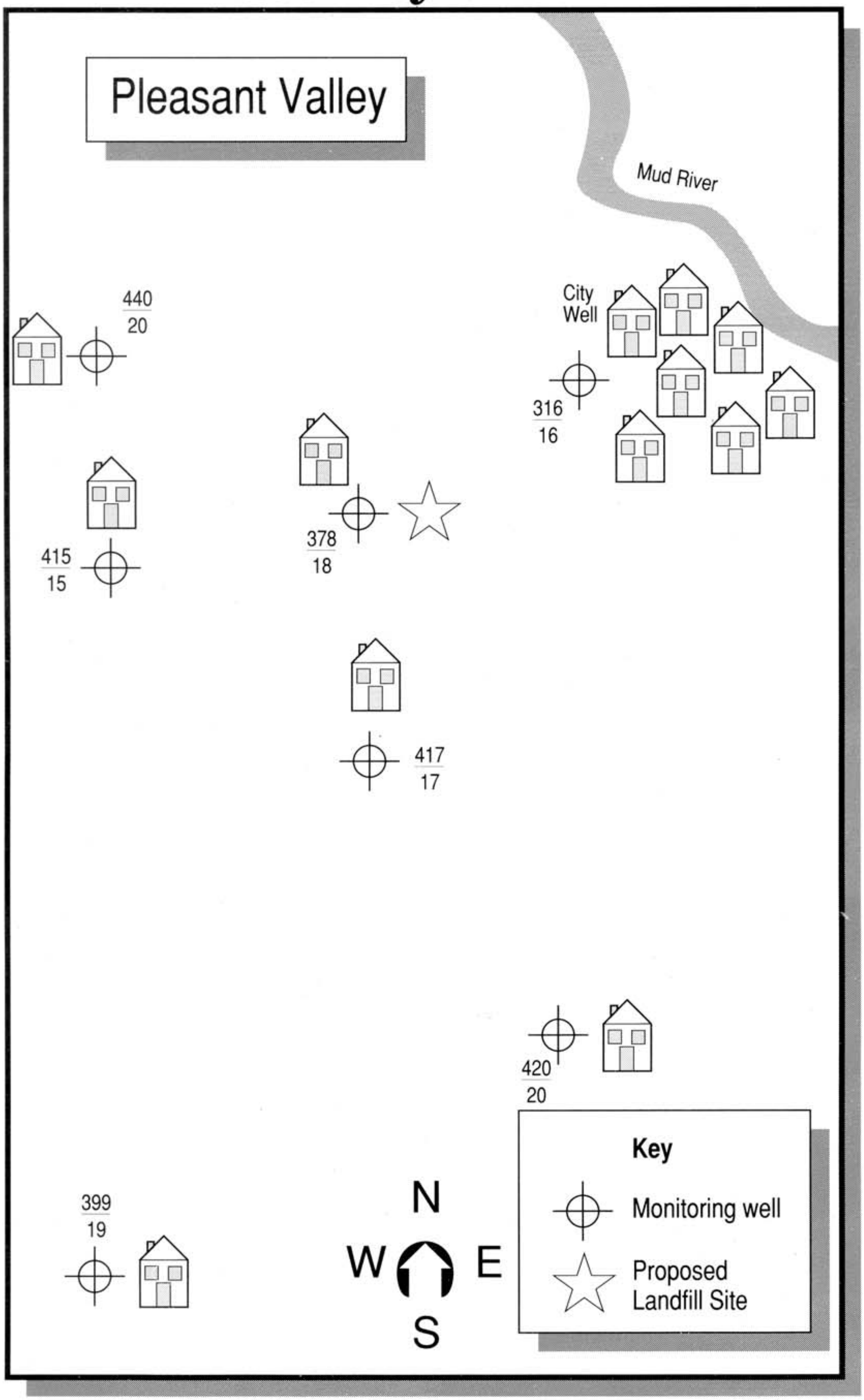
Storing household hazardous waste:

- Keep substances in original containers
- Keep a list of stored hazardous products, include the name and date of purchase.
- Be sure label is securely affixed to the container.
- Keep in a cool, dry place.
- Keep substances out of the reach of children and pets.
- If the original container leaks, enclose it in a larger container that is properly labeled.
- Keep incompatible chemical products separated.
- Periodically check containers for deterioration.

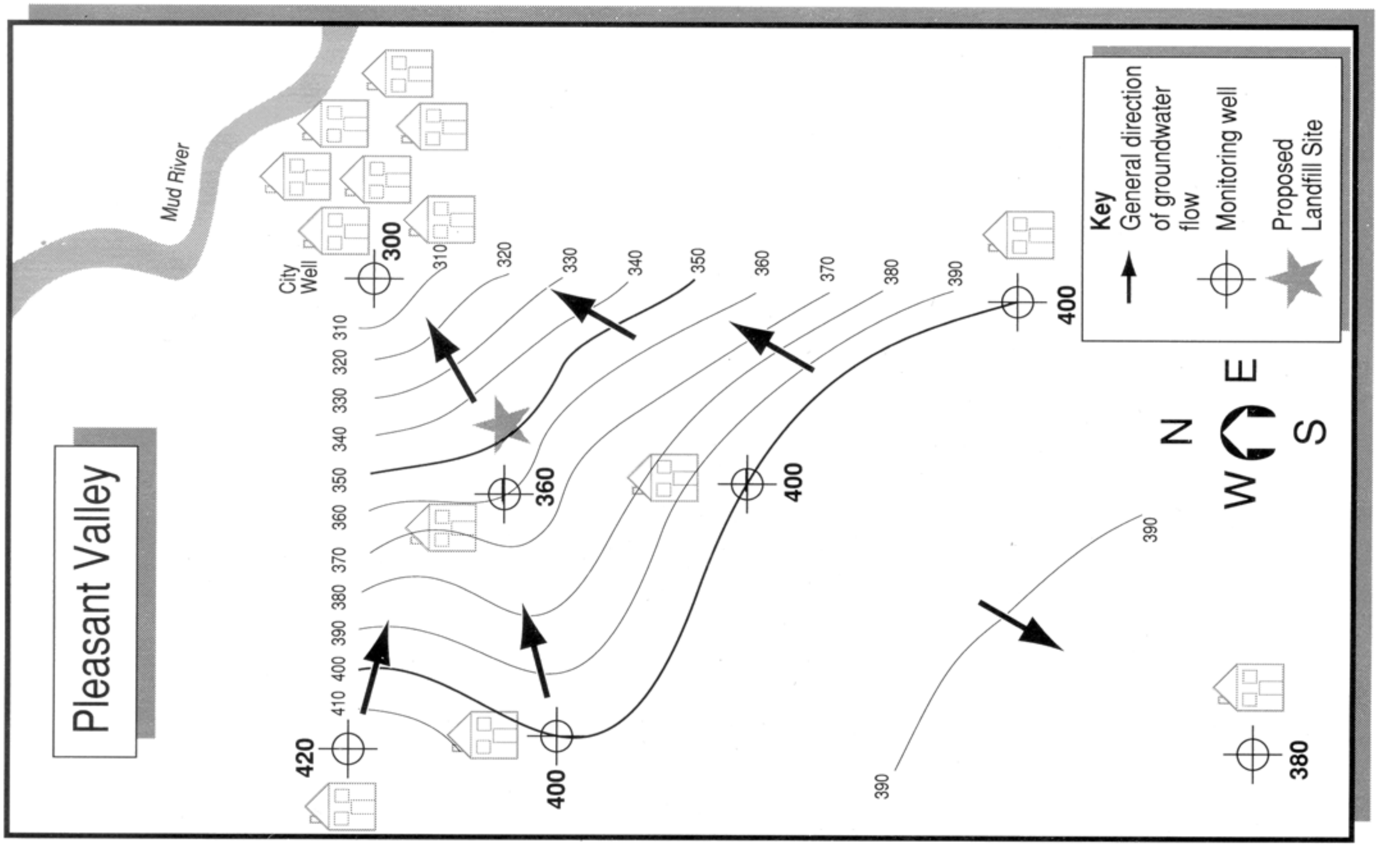
Using products that contain hazardous chemicals

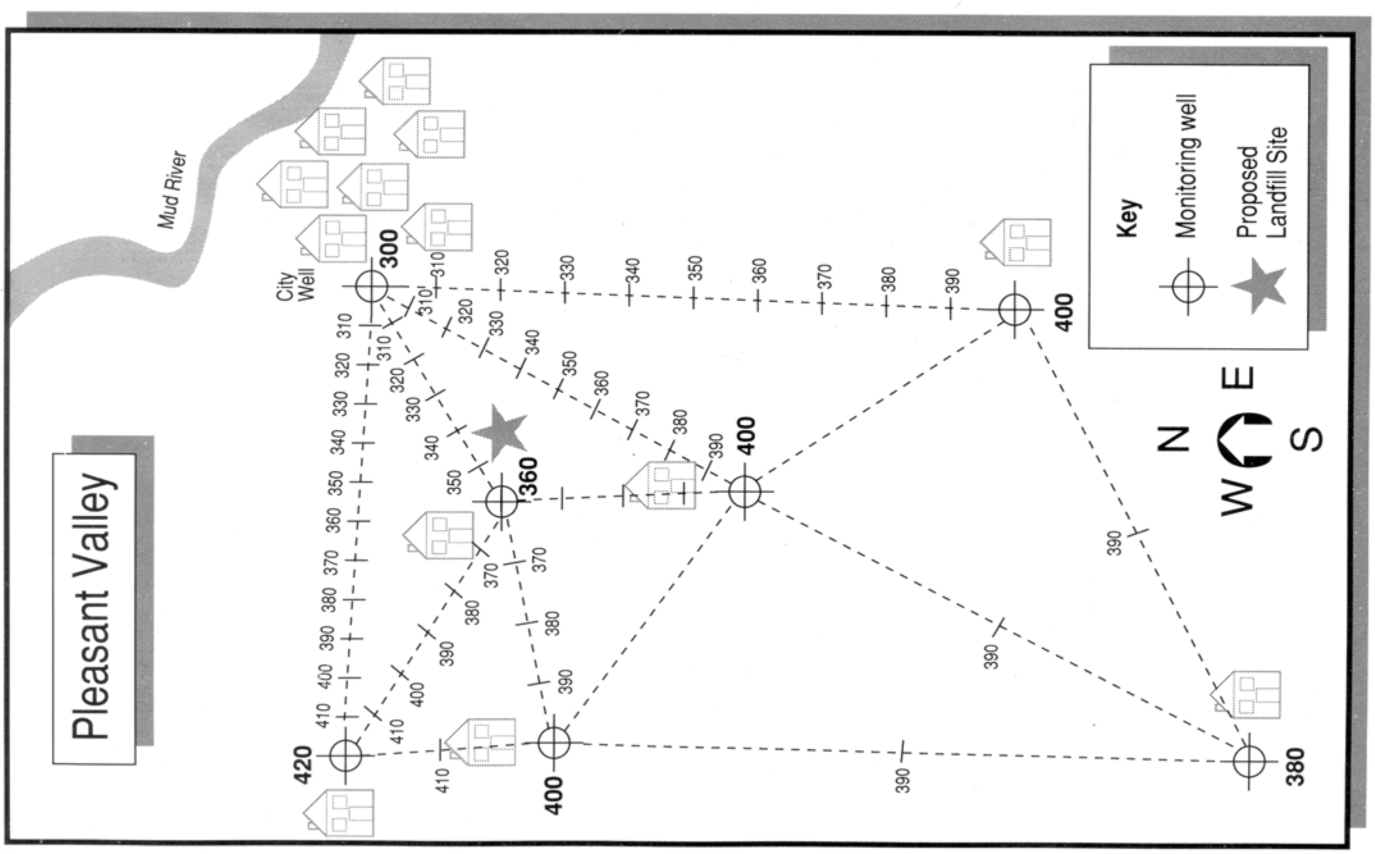
- Use natural, less toxic products or alternatives when possible.
- Carefully read and follow label directions
- Do not mix chemical substances.
- Buy only what you need; give leftover products in the original container to others who may use them.
- Use products in well-ventilated areas.
- Secure lids tightly before storeage.

It'll Go With the Flow activity sheet



It'll Go with the Flow Teacher's Key





What if Water Cost as Much as Gasoline? activity sheet

Sale on water! Only_______per gallon!

A) **Multiply the number of gallons of water listed after each use below by the price per gallon.** Put this answer in the space provided. An example has been done for you using the price of $1.00 per gallon of water.

example: Bath 30 gallons x $1.00 = $30.00 per bath

B) **Each time you use water:**

1. Put a mark (|) after the type of water use. Keep a tally of each use.
2. The price listed under "cost" will tell you how much to pay for that water use. Now put that amount of money in your envelope.

Use			Price Per Gallon		Cost Per Use		Check here each time you use water
Washing dishes by hand	10 gallons	X	________	=	________	each use	
Automatic dishwasher	11 gallons	X	________	=	________	each use	
Flushing toilet	4 gallons	X	________	=	________	each use	
Cooking & drinking	3 gal/day	X	________	=	________	each use	
Washing hands	1 gallon	X	________	=	________	each use	
Brushing teeth (water running)	2 gallons	X	________	=	________	each use	
Shower	18 gallons	X	________	=	________	each use	
Bath	30 gallons	X	________	=	________	each use	
Washing clothes	30 gallons	X	________	=	________	each use	

Groundwater Law activity sheet

Over time, four doctrines of groundwater rights have evolved in the United States. Each state treats groundwater conflicts differently, relying on one or more of the following doctrines as the basis for its groundwater use law.

1. English Rule:

Groundwater use is a property right under this doctrine. A land owner has the right to use the water under her land at any time and for any purpose. She may also sell or allow others to use her water.

2. Reasonable Use Rule:

Groundwater use is a property right, but water may only be used for "reasonable" purposes. A property owner may use the water on the land from which it came or elsewhere, as long as his use is reasonable in comparison with neighbors needs and uses.

3. Correlative Rights Rule:

All land owners in an area have a right to use groundwater. The amount of water each land owner can use depends on the amount of land she owns. She cannot pump more than her share of water, even for use on her own land if neighbors don't have enough water to meet their needs.

4. Appropriation Rule:

This is the rule of "first in time, first in right." Groundwater rights under this doctrine are not connected to land ownership. A person has a right to use groundwater if he has obtained it and put it to a beneficial use such as irrigation, mining, manufacturing, power generation, raising fish, watering farm animals, household or recreational uses. Water may be used on the land from which it came, or elsewhere. Appropriation rights may be sold or given to others.

Under the Appropriation Doctrine, in times of water shortage, those who have used the water longest may use all the water they have used in the past and newcomers may be left with little or no water. If a person stops using his share of water for a beneficial purpose, he may lose his right to use the water at all.

Groundwater Law in Wisconsin

There have been several key cases establishing Wisconsin's groundwater use law. Two of them are described here for you:

1. Huber vs. Merkel—Wisconsin Supreme Court 1903:

In 1903 a decision was made in the Wisconsin Supreme Court that influenced groundwater law for more than 70 years. This case involved two farmers, Mr. Huber and Mr. Merkel, who lived about 1/2 mile from each other. Both farmers owned flowing artesian wells.

Mr. Merkel had two wells on his property, one dug in 1899 and the other in 1900. Mr. Merkel used some of his water for a fish pond and some he sold to neighbors. Mr. Huber, like other land owners in the area, capped his well so that the water would not flow out when he was not using it. Mr. Huber's well was dug in 1899 and his farm is 20 feet higher than Mr. Merkel's.

There was enough water for both farms and neighboring homes until Mr. Merkel began letting his wells flow freely, maliciously wasting water to harm his neighbors. When Mr. Merkel's wells were allowed to flow, water levels dropped in all neighboring wells and some of the wells stopped flowing. Mr. Huber took Mr. Merkel to court to try to stop him from wasting water from his artesian wells.

The case was fought all the way to the Wisconsin Supreme Court. In 1903, the Supreme Court decided that the English Rule used in Wisconsin at the time meant that a land owner had an absolute property right to use water under his/her property. Since Mr. Merkel had an absolute right to use groundwater under his property, he could consume, sell or even waste water from his wells if he wanted. So Mr. Merkel won the case and Mr. Huber probably had to find a way to pump water from his once-flowing artesian well.

2. State of Wisconsin vs. Michels Pipeline Construction, Inc.—Wisconsin Supreme Court, 1974:

In 1972, Michels Pipeline Construction, Inc. was hired by the Metropolitan Sewerage Commission of Milwaukee to install a sewer line for the city. To bury the sewer pipe, Michels Pipeline had to lower the water table to 40 feet depth. The company dewatered the soil by pumping a lot of water (5,500 gallons per minute) in a nearby city.

When the water table was lowered some wells in the area dried up, others yielded less water, some began having water quality problems, and some foundations, basement walls and driveways began to crack because the land under them sank as the groundwater was drawn out.

The State of Wisconsin took Michels Pipeline to court because of the problems caused by dewatering the soil. The State wanted the Court to make the company construct the sewer line in a different way so the neighbors' water supply and property wouldn't be affected. They also wanted Michels Pipeline to fix the damage that had already been done.

The Court determined that pumping so much groundwater created a "public nuisance" and that by depleting neighboring wells, Michels Pipeline was actually taking property from people who lived in the area. The Court changed the course of Wisconsin's groundwater law by overruling the Huber v. Merkel decision. They felt that the old Common Law Doctrine was no longer appropriate for Wisconsin's needs. The case was decided instead on a modified Reasonable Use Rule. Our present groundwater laws are based on this rule.

Under the modified Reasonable Use rule a landowner may pump water from his/her land and use it for any beneficial purpose unless:

a) pumping the water causes unreasonable harm to someone else by lowering the water table or
b) pumping has a direct and substantial effect on a lake, stream or wetland.

It is still up to the courts to determine what is "unreasonable harm" and what is a "direct and substantial effect" on a lake or stream.

1. Let's go back to 1903. Imagine that you're on the Supreme Court and you are responsible for deciding the The Huber v. Merkel case.

a) Write a short paragraph explaining how you would decide the case using Wisconsin's modified Reasonable Use doctrine.

____

____

____

____

____

____

b) States, such as California, use the Correlative Rights doctrine. You are a Supreme Court Judge in California. Explain your decision on Huber v. Merkel, using the Correlative Rights doctrine.

c) You're on the Colorado Supreme Court in Denver. Explain how you would decide Huber v. Merkel, using Colorado's Prior Appropriation Rule.

d) Now, lets make your job a little more difficult. Assume that Mr. Merkel is not wasting any water—all of the water he lets run from his well is used to farm and to water a large herd of cattle. Choose the doctrine (or a combination of doctrines) to reach what you feel is the **most fair** decision in this case. Consider the positions of Mr. Merkel, Mr. Huber and all the other land owners. Remember, your decision could affect Wisconsin law for many years to come.

Trouble in Paradise activity sheet

The mythical town of Paradise is a rural township of about 5,000 people. Most residents run small farms or local services and businesses. The rolling countryside of the township has attracted urban workers in recent years from the nearby city of Crystal Springs and the town is experiencing its first major growth period in 20 years.

A small industrial area lies just west of downtown Paradise. This area includes a paint manufacturing company and a chemical plant. Both of these industries use water in their manufacturing processes and both produce chemical wastes. The paint and chemical companies were built in the late 1940's. In 1950, a municipal landfill was built west of the industrial site. The landfill accepted 500,000 cubic yards of municipal and industrial waste from 1951 until the landfill was covered in 1960.

The landfill site was sold to Jean Johnson for farming in 1962; the farm house was destroyed by fire in 1978, and the land was sold for suburban development in 1979. A gas station was opened near the farm site in 1980.

Through the late 1950's, all Paradise residents drew their drinking water from private wells. As more and more people moved into Paradise, residential neighborhoods expanded to the west and what had been farmland became suburban neighborhoods. In 1963 Paradise incorporated as a city. A new subdivision, Tranquil Acres, was developed between the industrial area and the Johnson farmsite during the early 1980's. Subdivision plans called for one high capacity well to serve the new homes. The well was installed in 1983 and began pumping water in March 1984.

In February 1983, members of the Hansen family began experiencing dizziness and headaches. The Hansen home is one of three remaining farms in Paradise and is located about 1/2 mile west of Tranquil Acres. Their home was built in the early 1900's and has its own private well. The Hansens suspected that their well water was causing their symptoms and in March 1983 they contacted the city health department. The city health department did not have the means to detect many contaminants, so they called in county health officials.

In May 1983, lab samples drawn by the county showed that the Hansens' well contained volatile organic compounds (VOC's), including benzene and and toluene. The well samples contained 350 ug/L toluene and 4 ug/L benzene. County health officials advised the Hansen family to use bottled water for drinking and to minimize contact with water by taking shorter, cooler showers, running the exhaust fan during showers, ventilating the bathroom after showering, and opening kitchen windows when running the dishwasher.

VOC	Sources	Health effects	HAL/MCL
Toluene	industrial wastes, dyes, solvents, perfumes, medicines, manufacturing of organic chemicals	irritability, disorientation, liver and kidney damage	* 68.6 ppb
Benzene	leaking gasoline tanks, industrial wastes, solvents for plastics, and paints	death, nausea, headache, unconsciousness, paralysis, CANCER	** 4 ppb
* Wisconsin Health Advisory Level (1989)	** EPA Maximum Contaminant Level (1989)		

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Between May 1983 and May 1984, local wells were monitored for VOC's. Each well was tested three times.

Well	June 1983		February 1984		April 1984	
	tol	benz	tol	benz	tol	benz
Hansen's farm	350	4	50	0	0	0
Thompson's farm	70	0	188	1	290	1
Smith's farm	0	0	0	0	0	0
Paint Company	0	0	0	0	0	0
High capacity well	0	0	0	0	0	0

Note: Results are in ug/L. 1 ug/L = 1 ppb.

The Hansens' well showed high levels of VOC's in June 1983, but only traces of VOC's in February 1984. By April 1984 the contaminants seemed to have disappeared from the Hansen well. In June 1984, the Smith's began to experience the same symptoms that the Hansens had experienced in 1983. The Smiths called the county health department to report the problem. Paradise officials decided a full scale investigation was in order. They feared that the contamination might be drawn toward the new high capacity well in the subdivision.

The area wells were sampled again in May and July 1984 with the following results:

Well	May 1984		July 1984	
	tol	benz	tol	benz
Hansen's farm	0	0	0	0
Thompson's farm	360	2	410	6
Smith's farm	200	0	260	1
Paint Company	30	0	30	0
High capacity well	0	0	0	0

Note: Results are in ug/L. 1 ug/L = 1 ppb.

Public health officials advised the Thompsons and the Smiths to use bottled drinking water and minimize contact with their well water. In addition to benzene and toluene, water tests revealed that the Thompson's well was also contaminated with methane gas produced by decaying organic material. Methane gas can be carried underneath homes by groundwater where, in high enough concentrations, it can cause explosions.

After hearing the results of the health department tests, residents of Tranquil Acres formed a citizen action group. They feared that the high capacity well was in danger of being contaminated. After several meetings citizens petitioned the city to:

1) Guarantee that the VOC problem be solved before the contamination spread to the new community well.

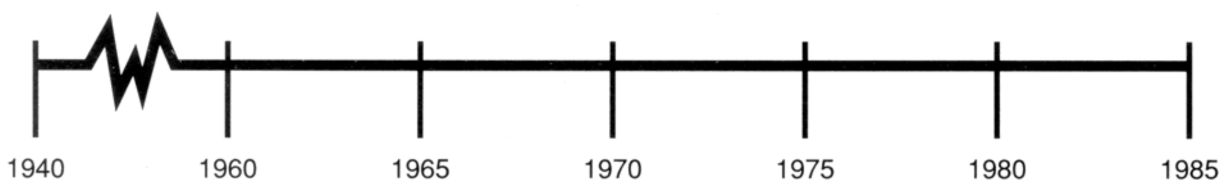
2) Guarantee alternate sources of water for contaminated wells.

3) Guarantee purchase of affected properties to maintain property values if the contamination problem cannot be solved.

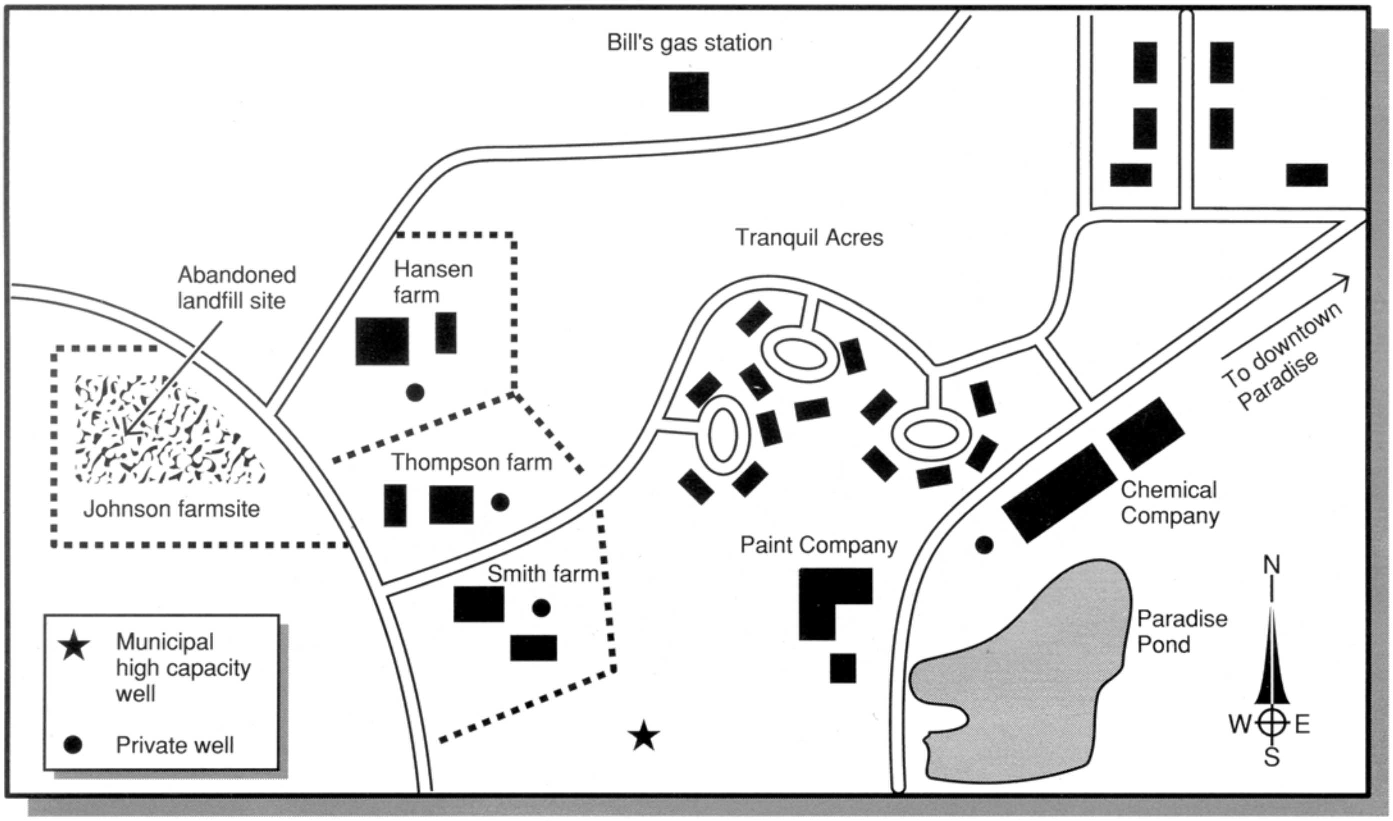
In August 1984, city council members determined that monitoring, testing and clean up could cost up to 3 million dollars. They have hired your company, the Contamination Busters, to help solve their groundwater problem before the community well is affected. Based on what you know about groundwater and the information you have been given, complete the following report sheet for the city council.

1. Place letters representing the following events on the timeline below:

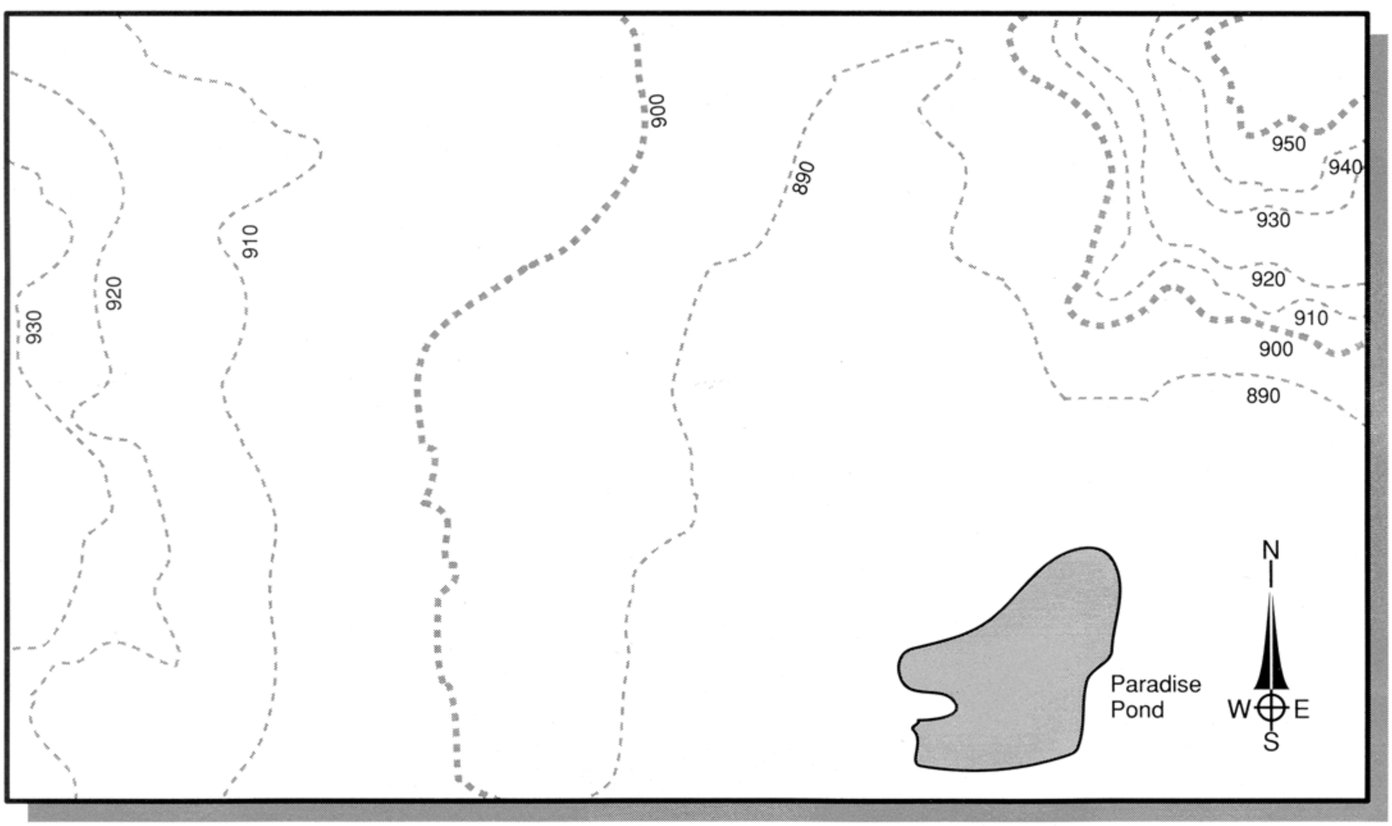
A — Tranquil Acres is developed
B — landfill is constructed
C — citizens form action group
D — landfill is covered
E — Smiths contact health department
F — local industries are built
G — city council decides to take action
H — high capacity well begins pumping
I — Bill's gas station opens
J — Hansens contact health department



2. Based on the topography of the Paradise area, draw an arrow on the map "B" showing the general direction of groundwater flow.


Bill's gas station
Tranquil Acres
Abandoned landfill site
Hansen farm
Thompson farm
Johnson farmsite
Smith farm
Paint Company
Chemical Company
To downtown Paradise
Paradise Pond
Municipal high capacity well
Private well
N
W
E
S

Map A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Map B

3. Complete the following tables.

Well	Parts per Billion Toluene				
	June 1983	February 1984	April 1984	May 1984	June 1984
Hansen's farm					
Thompson's farm					
Smith's farm					
Paint Company					
High capacity well					

Well	Parts per Billion Benzene				
	June 1983	February 1984	April 1984	May 1984	June 1984
Hansen's farm					
Thompson's farm					
Smith's farm					
Paint Company					
High capacity well					

4. Circle all VOC levels on the tables above that exceed Health Advisory Limits or Maximum Contaminant Levels.

5. Based on the information you have gathered, what is the source of VOC contamination?

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6. With a **Red** pencil place X's on map "A" in places where you'd like to put monitoring wells to confirm the source of contamination.

7. Using the information on the data tables above, outline the plume of contamination before the high capacity well was built with a **blue** pencil. With a **green** pencil, outline the plume of contamination after the high capacity well was began pumping. Why did the plume change?

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How Much is a Part per Billion? activity sheet

Many water quality standards are measured in parts per million, parts per billion, or even parts per trillion of pollutant in a given quantity of water. Regardless of what is being measured, ppm, ppb, ppt mean that there is one part of something in a million, billion or trillion parts of something else. The following table will help you understand this concept:

Unit	ppm	ppb	1 ppt
length	1 inch in 16 miles	1 inch in 16,000 miles	1 inch in 16,000,000 miles (a 6 inch leap on a journey to the sun!)
time	1 minute in 2 years	1 minute in 32 year	1 minute in 320 centuries
money	1 cent in $10,000	1cent in $10,000,000	1 cent in $10,000,000,000

A part per billion doesn't seem like very much. But consider the amount of material that would be involved in all the water the Los Angeles area uses in a year (3,000,000 acre feet) if these contaminants were present at the following levels:

Substance	1 part per billion in the water Los Angeles uses in a year would be enough to:
lead	make 1,000,000 bullets
chromium	plate 50,000 car bumpers
mercury	fill 4,000,000 thermometers
herbicide	kill all the dandelions in 100,000 lawns
insecticide	fill 5,000,000 aerosol cans of bug killer
gold	support 50 average families for eternity

Very small amounts of some pollutants can harm people and wildlife.

For example:

ppm	ppb	ppt
If there is 1 ppm oil in the water, 1/2 of the Dungeness crab will be killed	At levels of 20 ppd Hg in their blood, humans show symptoms of mercury poisoning	Brook trout cannot grow properly or reproduce at levels of toxaphene over 39 ppt.

Maybe a part per billion isn't so small after all!

*Adapted from C. Revelle and P. Revelle, **The Environment,** 1988, pp.112-114, Boston: Jones and Bartlett Publishers, Inc.*